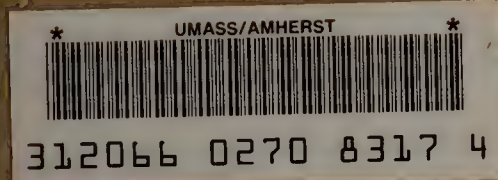


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DRAFT

ENVIRONMENTAL IMPACT REPORT
GYPSY MOTH CONTROL

SUBMITTED BY

DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
DIVISION OF FORESTS AND PARKS

MARCH 15, 1979

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The Commonwealth of Massachusetts

Department of Environmental Management

Division of Forests and Parks

Leverett Saltonstall Building, Government Center

100 Cambridge Street, Boston 02202

March 15, 1979

Mr. John A. Bewick, Secretary
Executive Office of Environmental Affairs
100 Cambridge Street
Boston, MA 02202

Dear Secretary Bewick:

Pursuant to Chapter 30, Section 62A and Section 10.05
(1) of the Regulations Governing the Implementation of the
Massachusetts Environmental Policy Act, I hereby submit,
for your consideration, the Draft Environmental Impact Report
entitled "Gypsy Moth".

Sincerely,

Gilbert A. Bliss
Gilbert A. Bliss
Director of Forests and Parks

APPROVED:

Richard E. Kendall
Richard E. Kendall
Commissioner

DRAFT ENVIRONMENTAL IMPACT REPORT

GYPSY MOTH

I BackgroundA. Susceptible Forest Types

The gypsy moth's food preferences make it a significant pest of several pioneer and subclimax forest types in Massachusetts. According to Bess, Spurr and Littlefield (2) the susceptibility of these various types to defoliation is not based solely on the presence of highly preferred food species in the overstory, but also on the character of the underlying soil and the physiography of the site. Their susceptibilities are listed in figure 1. Generally speaking the types that are listed as susceptible do not occur over substantial acreages or in great numbers at this time in Massachusetts, although their importance in the early history of the gypsy moth must have been significant since these pioneer types were abundant in the early 1900's on abandoned agricultural land and during the period following the 1938 hurricane. The types listed as borderline occur over substantial acreages in eastern Massachusetts on sandy soils and in western and central Massachusetts on dry ridgetops and south and southwest slopes. These forest types usually have understories of lowbush blueberry, sweetfern, sedges and bayberry that develop in the characteristically open stands that occur on these infertile soils. According to Bess, Spurr and Littlefield the susceptibility of these stands is due primarily to low populations of predators. The poor growing conditions associated with these sites make recovery from defoliation difficult, further compounding the adverse effects of the gypsy moth defoliation.

Resistant stands are those that generally occur on the moister sites and have a species makeup that includes a high proportion subclimax to climax species. The understories of these types typically include wild sarsaparilla, mapleleaf viburnum and various ferns associated with these moist sites. These

FIGURE 1

BESS, SPURR, AND LITTLEFIELD

TABLE 9

CLASSIFICATION OF FOREST COVER TYPES ACCORDING TO
SUSCEPTIBILITY TO DEFOLIATION BY GYPSY MOTH

Type S.A.F. No. ¹	Type Designation
SUSCEPTIBLE: Likely to be defoliated under a wide variety of conditions.	
4	Aspen
5	Pin cherry (with aspen and birch)
7	Gray birch
35	Scrub oak
BORDERLINE: Susceptibility depends upon site, actual composition and condition of stand.	
3	Red pine
6	Paper birch
36	Chestnut oak
37	Pitch pine
49	White oak-black oak-red oak
50	White oak
RESISTANT: Not likely to be defoliated unless badly abused or surrounded by susceptible types.	
7	Red maple
8	White pine-red oak-white ash
9-11	White pine types
12-15	Northern hardwood types
17-22	Spruce-fir types
26	Black oak-American elm-red maple
51	Red oak-basswood-white ash
—	Red oak
59	River birch-sycamore
60	Silver maple-American elm

¹Committee on forest types. Society of American Foresters. 1940. Forest cover types of eastern United States. Third edition, revised. Society of American Foresters. Washington, D.C. 39 pp.

lush understories usually have high populations of short-tailed shrews, deer mice and other predators that prey on the gypsy moth. Even though these types are rated as resistant they could be defoliated when intermixed with susceptible or borderline types particularly in times of high gypsy moth populations. The locations of these types in the Commonwealth can be ascertained from the Forest Type Map (figure 2) prepared by the New England Section of the Society of American Foresters. The Pitch Pine-Oak and Central Hardwood types and the Northern Hardwood and Spruce-Fir Types contain resistant types. One should bear in mind, however, that the distinction from one major type to another is not well defined, but is gradual with a great deal of overlap occurring near their borders due to differences in local physiography. It should be noted that the Pitch Pine-Oak and Central Hardwood types are not highly productive in their ability to produce commercial wood products although some local exceptions occur, particularly in the Central Hardwood Type. The Transition Hardwood and Northern Hardwood Types are most valuable from the standpoint of timber production. Well stocked, high quality red oak stands often have values in excess of \$1,500 per acre at maturity.

Each of these types or plant associations constitutes an ecosystem. All ecosystems, including forest ecosystems, are made up of the following groups of organisms:

- producers (plants) which convert sunlight (solar energy) to biomass,
- primary consumers which feed on the plants,
- secondary and tertiary consumers which feed on the plant eaters and meat eaters, and
- decomposers which break down the dead plant and animal material.

Because of the complexity of these ecosystems and the interrelationships of the organisms contained within, it is not possible to influence one portion of an ecosystem without profoundly influencing the other parts of it. For

Compiled by

COMMITTEE ON SILVICULTURE

SOCIETY OF AMERICAN FORESTERS

NEW ENGLAND SECTION

1955

Figure 2.

Committee on Silviculture

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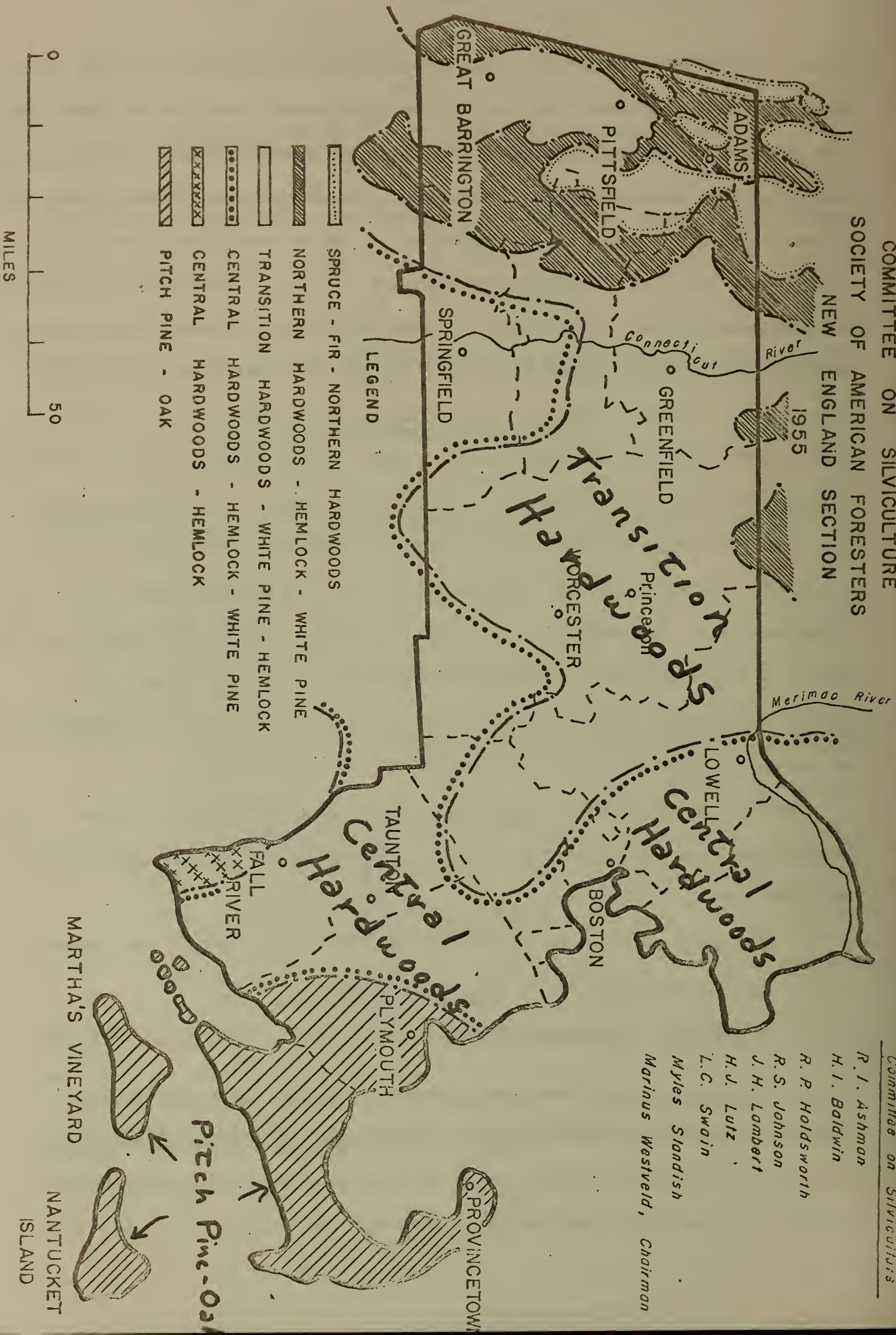
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Myles Standish

Marinus Westveld, Chairman



instance, it is not possible to severely defoliate and kill the oaks in a forest without beneficially influencing the other plants which grow there. This process, referred to as differential mortality creates a more diverse ecosystem if it occurs in a stand that is or is close to being a monoculture. This process also creates an ecosystem that is less susceptible to any one damaging agent (insects, disease, fire, flood, etc.).

The forest ecosystems found in Massachusetts by the European settlers in the 1600 and 1700's were the product of natural evolution with some intervention by fire caused by Indians to clear land and lightning and the frequent New England hurricanes. The latter probably did more to shape the presettlement forest than any other agent. Since settlement, man has had a profound influence on the Commonwealth's forest ecosystems. Most settlers regarded the forest as an obstacle to be overcome, and it was. By the early 1800's 2/3 of the land area in the Commonwealth had been cleared for agriculture. The development of shipping canals and, later, railroads made the more fertile lands of the West attractive to New England farmers who abandoned their land for the promise of a better life on the frontier. Naturally, the forests reclaimed this land and today Massachusetts is 56 per cent forested. Even though much of Massachusetts has returned to a forested condition, man's influence in many areas, particularly "suburbia" is profound;

"Man's progressive invasion of the forest has brought him into close--- and occasionally unwelcomed---contact with other members of the forest community. At the same time, his modification of the forest has changed drastically the environment of the plants and animals and has, at least in the areas when he has settled, greatly intensified existing problems and created new ones. The new problems are artificial---human problems---because man has imposed an arbitrary set of values upon his new environment, values that are irrelevant in the long-run biological realities of the forest." (7)

B. Introduction and Spread in Massachusetts

In the year 1869 a number of egg clusters of the gypsy moth (*Lymantria dispar* L.) were brought from France to Medford, Massachusetts by Mr. Leopold Trouvelot who was interested in conducting experiments in interbreeding this moth with silk worms and thus develop a hardy race of silk-producing insects. In the course of his rearing experiments some of the eggs were accidentally lost or some of the caterpillars escaped.

Numbers of the insect increased slowly at first. After 10 years it began to be noticed by local residents. Not until 1889, or 20 years after its introduction, did this insect become so abundant and destructive as to bring it into general public notice. The situation was so serious that the Commonwealth of Massachusetts appropriated funds and delegated to the Massachusetts Department of Agriculture the task of exterminating this pest. The infested area then covered 359 square miles surrounding Boston.

Despite the expenditure of hundreds of thousands of dollars in an attempt to eradicate the pest the gypsy moth continued its spread from its point of origin in Medford. By the year 1914 it had spread westward in Massachusetts to cover most of Worcester County, northward through Southern New Hampshire and Southern Maine and southward over all of Cape Cod, Rhode Island and Eastern Connecticut. Its most rapid spread was to the northeast. This, of course, was due to the fact that its major means of spread is the dispersal of first instar larvae by wind which in the spring blows from the southwest.

Despite the fact, however, that normal wind direction is from the southwest the gypsy moth did find its way to the Berkshires by the early 1930's and to isolated spots outside the generally infested area. It has been speculated, and, indeed, in some cases actually demonstrated that these outlying, isolated spots were the result of another means of spread of the gypsy moth. During

the pupation period the large mature caterpillars often spin their cocoons in protected areas. In the early days, spread occurred by means of freight cars or horse drawn wagons and later on trucks or automobiles. Upon emerging as an adult the female moth mates and lays her eggs near the spot when she pupated. If this happened to be the underside of a vehicle the mass would go where the vehicle would go. If during the following spring the eggs hatched far from their point of origin and in an area outside the generally infested area a new outbreak would take place if favored food could be found nearby.

Today the gypsy moth has become established in all of the New England states within the range of its favored food, the oaks. It has reached Western New York, all of New Jersey and Western Pennsylvania. It is far south as Delaware, Maryland, and West Virginia. It has become established in an isolated area in Michigan. It has been found in California and in Florida although possibly eradicated from these areas. Its recent movements can be attributed to the upsurge in the mobility of people since World War II. One of the greatest problems is the recent popularity of recreational vehicles.

C. Life History

The gypsy moth overwinters as an unhatched caterpillar within the egg. The eggs are laid in clusters containing from 250 to 500 eggs per mass on the average, although counts of over 1000 per mass have been noted. The eggs are laid in a wide variety of situations including the trunks of trees, the underside of branches, under bark flaps, in stone walls, under such things as picnic tables, or anywhere that seems to afford protection.

The eggs remain firmly attached throughout the winter and are generally unaffected by cold unless temperatures reach 25° below zero. Those eggs deposited in places which remain below snow level will hatch despite cold weather. (14)

The following represents defoliation records* by acres for Massachusetts from 1924 to the present:

<u>Year</u>	ACRES	<u>Year</u>	ACRES	<u>Year</u>	ACRES
1924	163	1942	36,715	1960	150
1925	48,321	1943	34,481	1961	3,000
1926	78,193	1944	225,637	1962	150,000
1927	131,880	1945	456,832	1963	87,847
1928	131,127	1946	217,132	1964	20,787
1929	95,078	1947	7,256	1965	17,232
1930	27,856	1948	32,386	1966	500
1931	86,694	1949	78,665	1967	909
1932	200,387	1950	4,979	1968	3,925
1933	157,003	1951	3,185	1969	6,060
1934	128,237	1952	82,372	1970	6,835
1935	108,097	1953	917,996	1971	18,787
1936	152,469	1954	118,095	1972	20,480
1937	393,613	1955	----	1973	43,970
1938	154,348	1956	3,830	1974	76,903
1939	143,292	1957	16	1975	17,895
1940	125,586	1958	8	1976	31,720
1941	263,369	1959	382	1977	133,234
				1978	63,042

*Animal and Plant Health Inspection Service, USDA and Massachusetts Division of Forests and Parks.

In the spring on approximately May 1st throughout most of Massachusetts, the eggs hatch. This coincides with that period of the year when the shadbush is in full bloom.

On a warm, sunny day the young, 1st instar larvae tend to crawl to the top of the trees. From this spot they spin silken threads and hang down. The winds at that time of year are generally from the southwest. The young, hairy caterpillars float on these winds, sometimes for great distances. After settling down on edible foliage the larvae begin to feed. Male larvae mature through five instars; females through six.

Pupation, or the resting stage, takes place after the caterpillars mature early in July. This stage lasts ten days to two weeks. At the end of this period adult moths begin to emerge. The males emerge first followed within a few days by the females. The males are strong fliers whereas the heavy bodied females normally do not move more than a few inches from the pupal case. The females emit a sex pheromone which attracts males from considerable distances. Following mating the female lays her eggs and thus completes the life cycle.

II Natural Factors Influencing Population Dynamics

Most of the natural factors exerting influence on the gypsy moth population are not clearly understood.

A. Weather and Climate

Weather and Climate undoubtedly play an important role in the cycle of gypsy moth outbreaks. It is well known, for instance, that in order to break dormancy, gypsy moth eggs must be subjected to a period of cold followed by warm temperatures. Following hatch the young caterpillar can be killed by low temperatures although the trees will also be damaged.

Wind as mentioned earlier in the statement plays an important part in the dispersal of the gypsy moth. So important a part that it was from this natural occurrence that the name gypsy moth was derived.

It has been generally believed that they could be carried by the wind for distances of twenty miles, but recent research has shown that most travel no more than about 400 feet in this manner. Even with strong sea breezes, or carried by winds on mountain ridges, the caterpillar will travel at most, three to five miles(16).

However, as a result of carefully conducted experiments, C.W. Collins(8) demonstrated that 1st instar larvae were born 13 1/2 miles by wind and he stated that "it is probable that the (known) limit has not been reached." Nowhere did Collins state that the majority from any one infestation was born that 13 1/2 mile distance. The important fact was that some were carried that far.

B. Predators

Birds play a role in suppressing gypsy moth populations but only to a

very slight degree. Campbell (5) mentions nuthatches, downy woodpeckers and scarlet tanagers as having been observed feeding on young larvae. He also mentions the black-billed and yellow-billed cuckoos being attracted to outbreak areas. They seem to specialize in eating hairy caterpillars such as the gypsy moth.

According to E.H. Forbush (9) numerous accounts from Europe in the 1800's tell of birds, particularly titmice, wrens and creepers, bringing gypsy moth outbreaks under control. He also writes of migrating flocks of cuckoos accomplishing the same thing. Observations made in Eastern Massachusetts by Mr. Forbush and others note that many species of birds attack the various stages of the moth. However, despite these and numerous other references to insectivorous birds we, nevertheless, have been, since its introduction, subjected to many gypsy moth outbreaks and undoubtedly will continue them in the future.

According to Smith and Campbell, birds and mammals consume 70 per cent of the pupae in sparse populations, which gives enough control to keep the population in check "indefinitely". They state, "Since the best way to cope with a problem is to prevent it, we feel that it would be wise to enlist birds and mammals in future attempts to control gypsy outbreaks. Their use is certainly one of the most promising biological control agents being considered.

The white footed mouse, Peromyscus leucopus, is also reported by Campbell(5) as being an important predator of the gypsy moth. It is only important, however, when the gypsy moth population is sparse. They attack larvae but are more apt to eat the pupae. Their population, however, does not increase significantly with an increase in gypsy moth population.

C. Parasites

The most important factors in the natural control of the gypsy moth are the imported parasites and predators. The introduced species which have

become established in Massachusetts are as follows:

Egg parasites; Oencyrtus kuwanae, Anastatis disparus

Larval and pupal parasites; Compsilura concinnata, Blepharipa pratensis,

Brachymeria intermedia, Brachymeria compsilura, Parasitigena agilis,

Apanteles liparidis, Apanteles melanoscelus, Sarcophagidae aldrichii

Predator; Calasoma sychophanta

Annually new species are being introduced into the State. Among those recent introductions, none of which have been recovered as yet, are the following:

Palexorista inconspicua, Exorista lavarum, Exorista japonica,

Blondelia nigripes, Apanteles liparidis.

D. Nucleopolyhedrosis Virus

This is a naturally occurring virus which passes from the adult gypsy moth to the eggs. Here again weather seems to play an important role in that hot, muggy days and nights coupled with overcrowding of the population seems to trigger an epidemic of the disease resulting in the ultimate collapse of the gypsy moth population.

E. Streptococcus Faecalis

A bacterial infection caused by streptococcus faecalis is also important in causing the collapse of outbreaks according to Anderson and Gould. (1)

III. History and Evaluation of Past Control Efforts:

A. Mechanical

Early efforts by the State in an eradication effort relied heavily on mechanical means. The scraping off and destruction of egg masses was one of the most effective, although it depended on the agility of the employees to reach all points in a tree. Another early method was the placing of burlap bands around the trunks of infested trees and the capture of the caterpillars which usually seek shelter during hot, sunny days, particularly in the later instars of development. The cutting and burning of favored trees also helped reduce future generations. The application of creosote to egg masses was found to be effective in destroying the eggs. Here again the effectiveness depended upon the ability of the employees to cover all parts of the tree.

B. Natural Predators and Parasites

In the year 1905 as a result of a tremendous increase in the gypsy moth the Commonwealth appropriated \$10,000 a year for three years for the investigation and importation of parasites and predators of this moth. These state funds were placed at the disposal of Dr. L. O. Howard, Chief of the Federal Bureau of Entomology. A. F. Burgess (4) thus began years of work, primarily by the Federal Government, to introduce natural enemies of the gypsy moth. Their introductions as well as some recent ones are listed in part II of this report.

C. Chemicals

The use of chemicals was attempted early, employing arsenate compounds such as Paris green and London purple. Although these were effective they damaged the tree foliage. About this time arsenate of lead was developed. From the 1890's to the end of World War II this

was the mainstay of the arsenal against the gypsy moth. High pressure spray machines with hose that could extend thousands of feet into the woods were used.

Following World War II and with the release of DDT to the general public a new approach to the control of the gypsy moth began. This was the application from aircraft of DDT in an oil base solution. Early experiments demonstrated that the insecticide applied at the rate of one pound of active ingredient per acre gave excellent control of the gypsy moth. One of the characteristics of DDT which later proved its undoing was its very long residual action. Those planning control efforts were not hampered by a short span of time in which to apply the insecticide. Effective control could be obtained by spraying prior to hatch knowing that it would still be toxic to the pest days later.

Massachusetts in the late 1940's and in the 1950's embarked on an eradication program in which thousands of acres were sprayed with DDT. Although the eradication effort was a failure, excellent control resulted. Areas sprayed with DDT for all intents and purposes remained free of gypsy moth for ten to fifteen years. Due, however, to its adverse effect on other forms of life the use of DDT was curtailed by this Department in 1964.

During the period of DDT use, the gypsy moth population continued to fluctuate substantially in Massachusetts. The year of greatest defoliation in Massachusetts was 1953. Some scientists feel that such fluctuations were partially a result of the use of this broad spectrum insecticide.

On the other hand records of the Division of Forests and Parks indicate that in the year 1954 a total of 97,723 acres in Bristol and Norfolk Counties were aerially sprayed to control the gypsy moth.

It was not until the year 1970 that scattered small spots of defoliation began to be noted in this area, a period of 16 years. It should also be noted that in the year 1963 a total of 110,000 acres in Hampden, Hampshire, and Franklin Counties were treated aerially to combat the gypsy moth. It was not until the year 1977 that a population buildup again began to be evident in this area, a period of 14 years.

Those charged with control of the gypsy moth then turned to Sevin (carbaryl) as a substitute. This material has remained the most commonly used shade and forest tree insect control agent to the present time.

IV Impact of Gypsy Moth Outbreaks

A. On Forest Trees

As stated earlier in this report Massachusetts is 56 per cent forested. 2,797,700 acres was classified as commercial forest land by the U.S. Forest Service in its 1972 inventory of the Commonwealth. Of this acreage, 87 per cent is in private ownership and the balance (13%) in public ownership. From this resource base, approximately 120 million board feet are harvested and processed each year by 620 firms employing 13,900 persons. The total value of industry shipments is 378 million dollars annually. It appears that demands on this resource will increase considerably in the future due to higher shipping costs brought about by energy shortages that affect the movement of lumber from the West Coast, the fact that substantial acreages of federal land are being withdrawn from timber production and a general increased demand for wood products.

Measuring the impact of a gypsy moth outbreak on the forest has been accomplished in the past. Records showing tree mortality and annual growth loss have been compiled. W. House in 1952 (11) estimated tangible losses due to the gypsy moth on forest trees in New England for the 1932-1952 period using 1952 values to be:

	<u>Cords</u>	<u>MBF</u>	<u>Value</u>
Mortality Losses	2,279,819	128,951	\$ 4,223,556
Growth Losses	<u>1,469,500</u>	<u>-----</u>	<u>2,419,536</u>
Total	3,749,319	128,951	\$ 6,643,092

Using current values monetary losses should be at least eight times that amount.

Factors other than the gypsy moth contribute to the tree mortality following an outbreak but would not have any effect if the trees were not first weakened by the defoliation. The two-lined chestnut borer, Agrilus bilineatus, attacks

weakened oak by feeding just beneath the bark. When numbers are sufficient, girdling results in the death of the tree. Another organism, also prone to attack weakened trees is shoe string root rot, Armillaria mellea. Attack by this root disease also results in the death of the tree.

Numerous studies throughout the Northeast have documented the effect of defoliation by the gypsy moth. Repeated defoliation has been shown to reduce growth, increase mortality, and possibly change stand composition. Reports conflict, however, as to the seriousness and significance of these impacts.

Brown, Halliwell and Gould's (3) observations of the impacts of gypsy moth defoliation in Rhode Island seem particularly relevant to the gypsy moth situation in Massachusetts in 1979. Their observations were taken in stands included in the Society of American Foresters Central Hardwood Type (figure 1) and is quite close (within fifty miles) to one of the major problem areas in the Commonwealth.

Their observations were in mixed oak, oak-pine and mixed hardwood stands. The infested stands had been heavily defoliated (60-100%) two years in a row, followed by one year of moderate defoliation (20-60%) and one year of low defoliation (0-20%). Nearby undefoliated stands of the same types were used as controls. Their characteristics are shown in table 1. (1) Mortality: "No trees that died during the study period were oak. Mortality of other hardwood species was low and probably normal for those species." Mortality was highest in the defoliated mixed oak stand and lowest in the mixed hardwood stand. Among species, the highest mortality was in white oak and among crown classes, 63 per cent of the mortality expressed as basal area was in the overtopped and intermediate crown classes. (2) Radial Growth: "Radial growth of oaks and white pine was greater during the predefoliation period than the years following defoliation. Generally speaking, the radial growth

loss for oaks was 32 per cent in the mixed oak and oak-pine stands and 40 per cent for oaks in the mixed hardwood stands." Analysis of other data, Campbell and Sloan, 1977 (6) indicates a recovery period of ten years following one year of defoliation before trees assume their predefoliation growth.

TABLE I

Characteristics of stands in defoliated and nondefoliated control areas in 1972.

Stand	Average d.b.h.	Dominants & <u>codominants</u>			Stems per acre	Basal area per acre	Species composition ¹			
		D.b.h.	Hgt.	Age			Black oak ²	White oak	Other hardwoods	White pine
	In.	In.	Ft.	Yrs.	No.	Sq. ft.	-----percent-----			
Mixed Oak										
Defoliated	4.0	5.5	36	37	721	84.0	67	31	1	1
Control	3.3	5.4	34	42	761	82.4	66	30	3	1
Oak-pine										
Defoliated	3.0	6.5	38	34	792	88.6	39	21	2	33
Control	3.4	8.4	42	61	600	121.8	39	14	3	44
Mixed hardwood										
Defoliated	4.1	9.1	55	73	630	141.2	13	16	40	31
Control	4.8	10.2	67	67	504	141.5	35	8	56	1

¹Based on percentage of total basal area.

²Black oaks include *Quercus coccinae* Muenchh., *Q. velutina* Lam., and *Q. rubra* L.

(3) Changes in Stand Composition: In the Rhode Island study the white oak was replaced by scarlet oak as the species making up the greatest proportion of total stocking. Similar relationships have occurred elsewhere (Campbell and Sloan, 1977) leading observers to conclude that differential mortality reduces the ratio of preferred or susceptible species in a stand and perhaps the susceptibility of the stand as well. Bess, Spurr, and Littlefield's (2) observations on the importance of understory vegetation and physiography of the site would negate this assumption.

Defoliation by the gypsy moth definitely has an adverse effect upon the productivity of oak stands. The degree to which stands are effected varies considerably, depending upon the makeup of the stand and various site charac-

teristics. During low and medium population levels the moth occurs primarily on only moderately productive sites that support mixed oak stands. While these stands are valuable from a timber standpoint the greatest economic losses occur when populations are high and infestations spread to transition hardwood stands on the more fertile sites that support a large proportion of northern red oak, primarily in western Massachusetts.

On sites such as these, mature, high quality northern red oak has a value range of \$100 to \$200. per thousand board feet and at maturity (80 to 100 yrs.) well stocked stands produce close to 15,000 bd. ft. per acre having a value of \$1,500 to 3,000 dollars. Growth of managed stands on these sites exceeds 200 bd. ft. per acre per year. At these values the net value of each years growth is worth \$20. to \$40. per acre. Although these site/stand characteristics do not make up the majority of our forest lands their acreage is considerable and extremely important in assessing the economic impacts of the gypsy moth. It should be noted that these economic losses are far reaching and extend beyond the immediate effects on the landowners. These losses also effect the supply of raw material available for the wood using industries, cited earlier in this report, of the Commonwealth and the jobs they create.

Of great concern to timber managers are the possible combined effects of the oak leaf tier (Croesia semipurpurana) and the gypsy moth. The tier complex has defoliated considerable (100,000 acres. 1977) acreage in Eastern Franklin and Hampshire counties in the past several years. Unlike the gypsy moth the tier complex is not site specific, it attacks oak stands across a wide range of site classes and its effects seem to be most severe on large dominant northern red oak. Perhaps this is due to the fact that the larvae stay in the trees through the daylight hours whereas the gypsy moth larvae usually descend each day.

The tier complex begins feeding on oaks at the time of leaf emergence; the gypsy moths heavy feeding begins later. In essence, a severe attack by both pests would result in the affected trees not being able to manufacture enough food reserves to refoliate and consequently suffer high mortality. There are no factual, local data available on the effects of this combination of pests. However, it is felt by many land managers that concurrent infestations by them could be disastrous and would warrant applying control measures.

The key to applying cost effective control measures in any forest pest situation is to develop predictive equations that take into consideration specific stand information (size, class species makeup, site productivity, etc.) and mortality data from previous infestations. While this may not seem to be a difficult task - it is. For the data to be useful it must be local and current. A great deal of information is available, particularly on the effects of the gypsy moth, but none on the oak leaf tier complex. The gypsy moth data is either local and old (reflecting a forest differing in composition from today's) or from another geographic region (reflecting the gypsy moth's introduction into the northern Appalachians). The Rhode Island data cited earlier in this report would not apply to these highly productive sites. To this end, the Bureau of Insect Pest Control and Forest Development have undertaken a joint study whereby previously established inventory plots are evaluated for insect damage. In addition, the Bureau of Insect Pest Control is monitoring starch levels in the roots of selected trees to determine what the correlation is between insect attack and mortality. Since these studies were initiated in the summer of 1978 and are, by their very nature, a long term proposition little useful data is available as yet. Once the data has been analyzed over a time span of several years it would seem that predicting mortality and financial losses would be easier and the task of weighing control alternatives easier as well.

As noted earlier in this report white oak is a highly preferred food of the gypsy moth. Some observers feel that there is a good deal less white oak in Massachusetts than there was earlier in this century.

There appears to be little likelihood that black, scarlet and red oaks will be replaced by other species on the dry, upland central hardwood sites in Southeastern Massachusetts since few species, except white pine, grow well there. The moist, fertile transition hardwood types in Western and Central Massachusetts could be seriously affected by the combined effects of the oak leaf tier complex and gypsy moth. On these sites high mortality of red oak would result in a much higher proportion of the maples than these stands now contain. Once this happened it would be extremely difficult to increase the stocking of oak in future stands since, unlike most other tree species, their seeds are heavy and cannot travel great distances like maple, hemlock, ash and pine seeds that are winged.

Northern red oak is one of the preferred timber species on these sites because with the exception of the gypsy moth and oak leaf tier, it has few natural enemies. In Massachusetts there has always been a steady demand for red oak timber and it commands high stumpage prices. Red oak normally produces a higher proportion of defect free lumber than other species growing on these sites, its growth rate is usually higher and it produces larger trees at maturity. Red maple, on these sites, generally produces a lower proportion of high grade lumber, grows slower, and is subject to many fungi that decay the butt logs. Also, red maples seldom reach the sizes attained by red oak nor is it as valuable to wildlife.

Mosher (13) arranged the food preferences of the gypsy moth according to the following classes:

Class I. Species that are favored food for the gypsy moth.

Class II. Species that are favored food for the gypsy moth after early larval stages.

Class III. Species that are not particularly favored, but upon which a small proportion of the gypsy moth larvae may develop.

Class IV. Species that are unfavored food for the gypsy moth.

Class I---Species that are favored food for the gypsy moth larvae

Alder, Spreckled	Oak, Rock Chestnut
Apple	Oak, Dwarf Chestnut
Ash Mountain	Oak, Bur
Aspen, American	Oak, Pin
Aspen, Large-toothed	Oak, Post
Balm-of-Gilead	Oak, Red
Beech, American	Oak, Scarlet
Birch, Gray	Oak, Bear
Birch, Paper	Oak, Shingle
Birch, Red	Oak, Swamp White
Blueberry (<i>V. angustifolium</i>)	Oak, White
Box Elder	Poplar, Lombardy
Gum, Red	Rose, Pasture
Hawthorn	Service-berry
Hazelnut	Sumac, Mountain
Hazelnut, beaked	Sumac, Scarlet
Larch, American	Sumac, Staghorn
Larch, European	Willow, White
Linden, American	Willow, Glaucous
Linden, European	Willow, Sandbar
Oak, Black	Witch-hazel

Class II---Species that are favored food for gypsy moth larvae after the earlier larval stages

Chestnut	Pine, White
Hemlock	Plum, Beach
Pine, Pitch	Spruce, Black
Pine, Red	Spruce, Norway
Pine, Scotch	Spruce, Red
Pine, Jack	Spruce, White
Pine, Western White	

Class III---Species that are not particularly favored but upon which a small proportion of the gypsy moth larvae may develop

Barberry, European	Fern, Sweet
Bayberry	Gale, Sweet
Birch, Black	Gum, Black
Birch, Yellow	Hickory, Bitternut
Blueberry, Low	Hickory Mockernut
Cherry, Sweet	Hickory, Pignut

Class III---(continued)

Cherry, Wild Black
Cherry, Wild Red
Chokeberry
Choke Cherry
Cottonwood
Cranberry, American
Elm, American
Elm, European
Elm, Slippery

Hickory, Shagbark
Hornbeam, American
Hophornbeam
Maple, Norway
Maple, Red
Maple, Silver
Pear
Poplar, Silver
Sassafras

Class IV---Species that are unfavored food for the gypsy moth larvae

Arbor Vitae
Arrowwood
Arrowwood, Maple-leaved
Ash, Black
Ash, Blue
Ash, Red
Ash, White
Azalea, White and Flame
Balsam, Fir
Blackberry, High
Blue-flag, Larger
Butternut
Catalpa, Hardy
Cedar, Red
Cedar, Southern White
Cornus
Cranberry-tree
Currant Red
Cypress, Bald
Laurel, Sheep
Locust, Black
Locust, Honey
Maple, Mountain
Maple, Striped
Mulberry, Red
Mulberry, White
Osage Orange
Osier, Red
Pepperbush
Persimmon
Privet
Raspberry

Dangleberry
Dock, Narrow
Dogwood, Flowering
Elder, American
Eubotrys, Swamp
Feverbush
Grape
Greenbrier
Hackberry
Hardhack, Pink
Hardhack, White
Holly, American White
Honeysuckle, Bush
Huckleberry, Highbush
Inkberry
Ivy, Poision
Juniper, Common
Kentucky Coffee-tree
Laurel, Mountain
Sarsaparilla
Skunk Cabbage
Spice-bush
Sweetbrier
Sweet Pepper-bush
Sycamore
Tea, Appalachian
Tulip-tree
Viburnum, Sweet
Walnut, Black
Willow, Bay-leaved
Winterberry, Smooth
Winterberry, Smooth

In arranging the foregoing classes it was not easy in all cases to assign a food plant according to this arbitrary classification. A number of species such as the poplars and hickories belong near the border line of Classes I and II, and they have been rated in the list which seems most appropriate. In general, it can be said that whenever any of the trees or shrubs in Class IV are growing together no injury from gypsy moth attack need be feared, and the same is true of Class II, or a combination of Classes II and IV. In case of any of the species given in Class III are present there is a slight chance of injury resulting, but for practical purposes, no difficulty is likely to be experienced by an owner so long as the species given in Class I are not present in his wood land or on his private grounds.

An examination of these classes, however, shows that the species noted in Class I are at present the dominant species in the woodlands in the area now infested with gypsy moth. The oaks and birches predominate over much of this area, and this increased the difficulty of remedying the situation.

It will be noted that most of the species of high commercial value are included in Classes I and II. In arranging combinations which will resist moth attack, it is necessary to consider the soil and other conditions suitable for their successful growth and to endeavor to bring about replacements with the least possible expenditure of money.

B. On People

Today in Massachusetts the severity of a gypsy moth outbreak is also measured by the numbers of affected homeowners as well as the total acres of forest under attack. Much of the Commonwealth supports susceptible to borderline types. This is particularly true in the eastern part of the State and out to the Connecticut Valley. These forest types are subject to attack by the gypsy moth.

Unfortunately many homes in many communities have been constructed in or closely adjacent to this susceptible forest land. When subjected to a severe outbreak the adjacent forest land as well as the shade trees surrounding the homes are stripped of the current years foliage, the caterpillars in later instars tend to wander, frass and bits of chewed leaves fall onto anything under the trees, and in general they create a mess. Although severely defoliated oak trees will refoliate within a few weeks, the homeowner loses, for that period of time, the benefits and enjoyment which he expects from his trees. It is very difficult for someone living outside the infested area to appreciate the consternation and frustration of someone living within an infestation.

Where there is a choice, developers should be encouraged to remove white oaks when building in forested areas. According to Michael J. McManus, U.S.D.A. Hamden, Connecticut, developers generally leave the largest trees, which may be white oaks, thus making a development more susceptible than necessary to gypsy moth infestation.

Although text books and reference books refer to the gypsy moth as a forest pest, in reality, at least under Massachusetts conditions, it should also be classed as a shade tree or backyard pest. Whenever vast acres of forest land are defoliated certain changes in the ecosystem must be expected. Subtle changes take place in both flora and fauna when five or six weeks of sunlight reaches the forest floor. In terms of tree mortality, however, little is experienced in Massachusetts today as opposed to reports dating back thirty or forty years or more. There are localized exceptions but in terms of total acreage these represent only a very small percentage. It is the effect of gypsy moth on people that creates the most impact by today's standards.

Managers of commercial campgrounds are concerned with the impacts of nuisance, defoliation and tree mortality on the enjoyment of natural beauty. In addition, they are concerned with the impact of nuisance on property value and on maximizing recreational use. The managers of both public and quasi-public recreation areas are most concerned with the impacts of nuisance and defoliation on enjoyment of natural beauty and on maximizing recreation use. George H. Moeller, et al (12)

The above would also apply to state, county, or municipal recreation areas. With few exceptions one of the basic ingredients in a recreation area is trees. Although a gypsy moth outbreak in one or more of these areas would allow anyone interested to study a phase of a naturally occurring phenomenon, a camping area or a picnicking area devoid of foliage on the trees is not attractive to a majority of users of these facilities.

Another problem which faces managers of both private and public recreation areas is the Federal agency, Animal and Plant Health Inspection Service, whose responsibilities are taken up elsewhere in the statement. It has the power to inspect and require removal of any gypsy moth stage of development found.

V. Present Status of Gypsy Moth in Massachusetts

A. Current Situation

Difficulty arises when the decision must be made as to whether to wait for the collapse of an outbreak or to apply control measures. Waiting subjects the homeowners or forest owners to three or four years of gypsy moth outbreak and the subsequent problems. Spraying, properly timed and applied alleviates the problems created by the gypsy moth for the current year. If a large enough area receives the treatment it should remain relatively free of the gypsy moth for the duration of the outbreak.

Although attempts are being made to add to it, the presently established parasite - predator complex in Massachusetts is effective. The length of time between cycle peaks of the gypsy moth is governed primarily by the activities of the parasites and predators when the total gypsy moth population is depressed following the collapse of an outbreak. It is at this time that parasite activity plays its most important role. Cycle peaks and depressions in Massachusetts and other New England states are similar to those experienced in Europe where the insect is native. Parasite and predator activity during the low period of gypsy moth cycle tends to keep the population depressed for a number of years.

In the year 1895, officials in Massachusetts wrote to like officials in many countries in Europe and Asia concerning the gypsy moth. Numerous replies were received and are retained as Department records. One such reply from Germany contained the following quote from a paper written in the year 1769 entitled "Bumerkungen Uber Die Stamuraupe" (Remarks Concerning the Gypsy Moth) part of which is as follows: "One sees generally that if the caterpillars have preserved themselves happily for several years and increased to such an extent that we expect in the following year terrible ravages, all at once everything seems to be gone and usually seven years pass by before we observe the same thing again."

Eventually the gypsy moth begins to outdistance its natural enemies and a rise in population takes place. Although the natural enemies increase in numbers as the available host population increases there is a time lag which allows an outbreak to become full blown.

Generally speaking it is safe to say that any gypsy moth outbreak will collapse within a three or four year span. A situation is considered outbreak when visible defoliation is evident. When the gypsy moth population builds to numbers more than can be sustained by the amount of foliage present the population begins to weaken due to competition for the available food. A couple of days of warm, muggy weather is all that is needed to trigger the nucleopolyhedrosis virus disease that is always present in a gypsy moth population. The "wilt" disease then proceeds to decimate the population.

The accompanying map entitled "Gypsy Moth Defoliation - 1978" indicates the current extent of the gypsy moth outbreak in Massachusetts. Total visible defoliation observed in 1978 was down from the total of 133,000 acres recorded in 1977. Massachusetts, although far from being free of the gypsy moth, shows less acreage in 1978 as compared to 1977, and it is still intense in certain communities. It would be impossible at the time of this writing to pinpoint the potential 1979 problem areas. These determinations can only be made following an egg mass survey. From this survey numbers of egg masses per acre can be related to potential gypsy moth populations and it is expected that on a statewide basis total acreage will increase in 1979. Only the location of the problem will change.

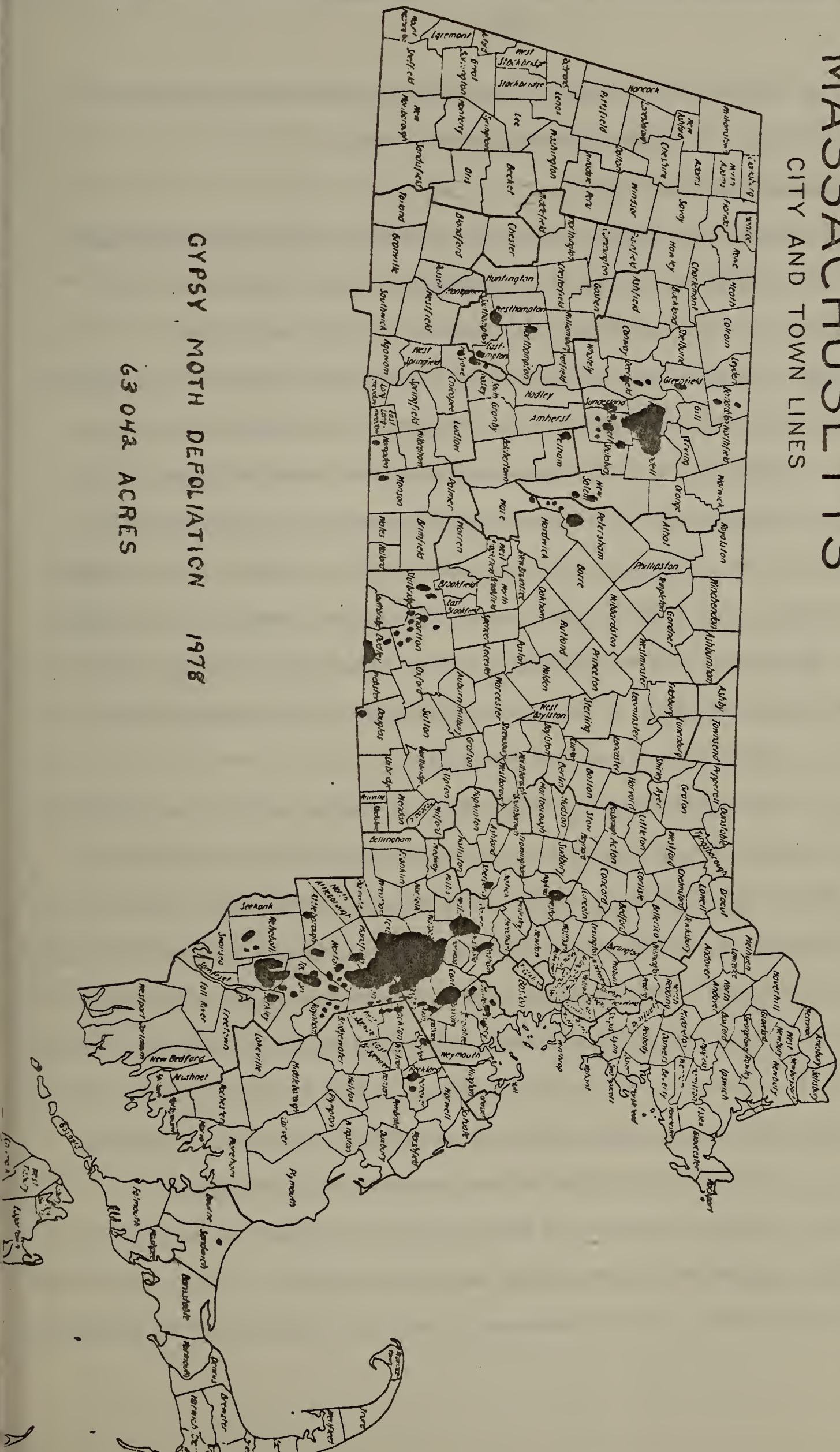
Predictions are based on counts of visible egg masses made during the fall and winter after egg laying is completed and before hatch the following spring. A series of 1/10 acre plots within the area suspected of containing gypsy moth are established. All viable egg masses visible to the observers are counted. From these counts it is possible to predict the amount of defoliation to be

MASSACHUSETTS

CITY AND TOWN LINES

GYPSY MOTH DEFOLIATION 1978

63 042 ACRES



expected during the following season. The general size of the egg masses is taken into consideration before the prediction is made.

B. Agency Responsibilities

Bureau of Insect Pest Control, Division of Forests and Parks, Department of Environmental Management has certain responsibilities as mandated by the legislature and set forth in Section 4C, Chapter 21, G.L. as follows:

"The bureau of insect pest control shall perform such duties as the director, with the approval of the commissioner, may require. In addition to such other duties as may be invested in it by law or by assignment from the director, the bureau shall be responsible for all tree spraying projects on state property. It may, subject to the approval of the director, other provisions of the General Laws or any special laws to the contrary notwithstanding, require to be carried out under its direction all tree spraying or other treatment which may be performed by other departments, agencies or political subdivisions of the Commonwealth."

Section 11, Chapter 132, G.L. further states:

"The chief superintendent may, subject to the approval of the commissioner, make rules and regulations governing all operations by cities and towns or persons for the purpose of suppressing gypsy and brown tail moth, tent caterpillars, cankerworms, oriental hag moths, fall webworm, Japanese beetle, saddled prominent, pine looper, and elm leaf beetles, which destroy forest and shade tree foliage, diseases and leaf eating and sucking insects which damage forests and shade trees, the Dutch elm disease and the beetles which spread said disease, woodticks, and poison ivy growing within one hundred feet of any public way, all of which are hereby declared to be public nuisances for the purpose of this chapter.

He may make contracts on behalf of the commonwealth: shall study and promote improved methods of suppressing such public nuisances; may act in cooperation with any person, any subdivision of the commonwealth, any other state, the United States,

or any foreign government, and without limiting the generality of the foregoing shall act in cooperation with federal and state agencies engaged in the study of control of said public nuisances; may conduct investigations and gather and distribute information concerning such public nuisances; may advise, make use of and require the use of all lawful means of suppressing such public nuisances; may lease real estate when he deems it necessary; and with the approval of the authority in charge, may use real or personal property of the commonwealth.

He shall prepare for students or for the public such lectures, exhibits or information relative to such public nuisances as may be required, shall personally and by employees of the bureau of insect pest control supervise operations undertaken by cities and towns to suppress such nuisances, and the expenditure of funds therefore; and for such purposes may employ such assistants and agents, including expert advisors, as he deems necessary. For the purpose of this section he may expend such sums as may be appropriated or donated therefore but no expenditure shall be made or liability incurred in excess of such appropriations and donations. He shall annually recommend to the commissioner the financial liability as described in section fourteen, of each city and town, to be appropriated by said city or town to be expended by the local superintendent for such suppression work within said city or town. No owner or occupant of an estate infested or infected by any of the aforesaid public nuisances shall by reason thereof be civilly or criminally liable except to the extent and in the manner and form set forth in this chapter."

Annually the Bureau evaluates, statewide, the current gypsy moth situation. This is accomplished by means of an aerial defoliation survey followed by an on the ground egg mass survey. The information from these surveys allows experienced Bureau personnel to predict the extent and severity to be expected during the following season.

In recent years this information has been passed along to the affected communities and the decisions to control or not control left to local officials. The Bureau has attempted to outline the various alternatives, again leaving the final decision up to the municipality.

Animal and Plant Health Inspection Services (APHIS), U.S.D.A.

The responsibilities are to prevent artificial, long-range spread of the insect and to eradicate incipient remote infestations within the United States through judicious use or registered insecticides and biological methods.

When a significant number of egg masses are found on a park or recreation area in Mass which caters to large numbers of vacationers and travelers from other states, particularly those outside the generally infested Northeastern U.S., this agency has the responsibility of preventing the movement of the gypsy moth out of the area. Two methods are employed: The first is the applications of an insecticide resulting in the knockdown of the populations thus eliminating potential spread. The second, if spraying is not possible, is the examination of each vehicle as it leaves the recreation area and the destruction of any eggs, larvae, or pupae if found.

Environmental Protection Agency (EPA)

This Agency has no direct responsibilities regarding the gypsy moth. Indirectly any contemplated control measures over and above strictly mechanical means requires input from E.P.A. All insecticides, both chemical and biological, must be registered with this agency and must be labeled for use against the gypsy moth including specific directions for rate of application, type of equipment and where the application can be made. Any warning concerning toxicity and hazards are also included on the label. EPA also has the responsibility to make sure that all statements and instructions on the label are complied with by both the manufacturer and the user.

Massachusetts Pesticide Board has the responsibility for the following, thus making it directly related to any control operations directed against the gypsy moth. It "Regulates the transportation, sale, storage, and use of pesticides, registers pesticides, issues permits for the experimental use of pesticides, licenses dealers in restricted use pesticides, certifies those who use or supervise the use of restricted pesticides, licenses certain investigations relative to pesticides sold and use, and enforces the laws and regulations pertaining to pesticides."

City and Town responsibility regarding the gypsy moth as with the Bureau of Insect Pest control can be found in Chapter 132 Section 11 of the General Laws of the Commonwealth. Gypsy moth has been declared a public nuisance and therefore responsibility for its control rests within the communities where it is found.

VI Possible Control Actions

A. Biological

1. Parasite Release

a. Release of insect enemies of the gypsy moth indigenous to those lands where the gypsy moth is native has been covered elsewhere in the statement. Thanks to the cooperation of the U.S.D.A. new releases are being made in Massachusetts each year.

b. Inundative releases of certain parasitic species have thus far proven unsuccessful in accomplishing a significant reduction in a gypsy moth population. D.G. Grimble (10) states that the supplemental release of about 19,700 adult Apanteles melanoscelus in 1974 failed to increase the level of parasitism by the species and, in fact, produced no measurable impact. He also stated that the inundative release of about 77,000 adult Brachymeria intermedia did cause a significant increase in parasitism within 30 chains distance of the release points during 1974. That increased rate of parasitism in 1974 was due in part to a greater effectiveness of the parasite under conditions of nearly total defoliation, and disappeared during the next season when defoliation did not occur. The gypsy moth population collapsed in 1974 due to wilt disease.

2. The aerial application of nucleopolyhedrosis virus, a pesticide recently registered and given a label by EPA, shows promise but as yet has not been demonstrated as a control agent on a large scale. Under certain natural conditions the virus will reduce a gypsy moth outbreak to a point where it is difficult to find any evidence of live individuals.

3. The bacterial form, Bacillus thuringiensis, has been produced for a number of years on a commercial basis as an insecticide to be used against certain Lepidopterous insects including the gypsy moth. It is specific only to those Lepidoptera. Its record against the gypsy moth is

erractic. Control is good in some cases and poor in others. Work is continuing to find a more potent strain.

4. Much has been said in recent years about the control possibilities of the synthetic sex attractant, disparlure. It has been demonstrated that it is not effective when applied to a heavy population. It does show promise when applied to a very light infestation. Its greatest usefulness is in the baiting of traps used to detect the presence of the gypsy moth in areas outside the generally infested area of the northeast.

5. The release of sterile males has been studied for a number of years as a means of controlling the gypsy moth. The greatest problem encountered in this has been that of producing large enough numbers of sterile males to inundate an area. At the most, under laboratory conditions, only two generations of gypsy moth can be produced in one year. The numbers required to effectively compete with natural males would require manpower and facilities far beyond what would at this time be considered reasonable.

B. Chemical

1.. General

Sevin (carbaryl), Dylox (trichlorfon), Orthene (acephate) and Dimilin (diflubenzuron) are registered and labeled by EPA for use against the gypsy moth.

Each of the above when applied at the proper time and according to label directions will result in good to excellent control. Past experience of the Bureau of Insect Pest Control indicates that more lasting results are achieved when the total outbreak area is sprayed. Conversely if no spraying is done there will be repeated defoliations until there is a natural collapse of the population. Repeated defoliation results in the impacts referred to earlier in the statement.

The environmental fate, the potential for human and wildlife effects, and relevant chemical parameters of the above named pesticides have been reviewed and summarized briefly by a contracted consultant and the report becomes part of this statement.

The following is a summary of the results of an investigation to identify potential problems which may be associated with the use of carbaryl, acephate, diflubenzuron and trichlorfon.

It is important to stress the preliminary nature of the summaries. To determine the probable effect of these pesticides, if they were to be used in a gypsy moth program in Massachusetts, would require:

Examination of the original literature wherever possible.¹

A determination of the organisms (including humans) which would be exposed in a proposed application, the application rate to used, and the characteristics of the soil and water mediums which could transport the pesticides and lead to indirect exposure of other organisms.

An integration of the above, combining the potential for the effect with the amount of exposure, in an assessment of populations at risk.

Regarding the following summary statements, the reader should also keep in mind the numerous limitations of laboratory studies which comprise most of the supporting data. Laboratory tests in general are based on extremely artificial exposure situations. For instance, the organisms are often exposed to large amounts of the pesticide over a short amount of time in an effort to assess the effects of long-term chronic exposure. However, at present these lab procedures constitute the only means for indicating potential problems and comparing alternative pesticides.

¹Only secondary sources which were immediately available were used in this assessment because of time constraints.

CARBARYL

Carbaryl, also called dicarbam and Sevin[®] is a carbamate compound with the following structure:



1-Naphthyl methylcarbamate

Carbaryl is a contact and stomach poison insecticide with slight systemic properties. It is a white crystalline solid with a low vapor pressure of 0.005 mm mercury at 26°C. It has a low solubility in water (40 ppm at 40°C). It is soluble to 10% in xylene and 20% in methyl isobutyl ketone (White-Stevens, 19).

MAMMALIAN TOXICOLOGY

Metabolism - The metabolism and degradation of carbaryl have been studied extensively in microorganisms, plants, insects and mammalian systems (Menzie, 1974). In most systems, carbaryl is readily metabolized to less toxic metabolites. The predominant metabolites are 1-naphthol and its conjugates; other hydroxylated metabolites are found in relatively minor quantities (NAS, 1977).

Human Exposure - Male volunteers ingested 0.06 or 0.13 mg/kg of carbaryl daily for six weeks. Blood chemistry, urinalysis, stool examination and electroencephalographic studies suggested no substantive changes that were attributable to carbaryl. A slight decrease in ability

of the proximal convoluted tubules of the kidney to reabsorb amino acids was noted in the 0.13 mg/kg group but these slight deviations were reversed and absorption returned to normal after ingestion of carbaryl was stopped (Wills, et al., 1968).

A number of reports of occupational or accidental exposure to carbaryl are available. None of these indicate a significant hazard to man from carbaryl exposure and, in general, fatal human poisoning from carbaryl exposure is extremely rare (NAS, 1977). Carbaryl exerts its insecticidal effects by inhibiting cholinesterase activity (i.e., affects the central nervous system); this effect, however, is reversible in man.

Experimental Animals - Carbaryl induces moderate acute toxicity in laboratory animals. Oral LD₅₀ values for carbaryl range from 280 mg/kg in guinea pigs to 710 mg/kg in rabbits. The dermal toxicity of carbaryl is quite low. An acute dermal LD₅₀ value of greater than 4000 mg/kg has been reported for the rat (USDA, 19__).

A dosage of 104 mg/kg/day was reported to produce no adverse effects in a 90-day chronic feeding study conducted with rats whereas 167 mg/kg/day reduced growth, increased liver weight and slightly decreased cholinesterase activity (Union Carbide Corp., 1958a).

In a two-year feeding study with rats, the no-adverse-effect dosage was 8.2 mg/kg/day; 18 mg/kg/day reduced growth and produced transient cloudy swelling of kidney tubules and cloudy swelling of central hepatic cords (Union Carbide Corp., 1958a).

No adverse effects were observed in dogs given 7.2 mg/kg/day of carbaryl by capsule five days per week for one year (Union Carbide Corp., 1958b).

Mutagenicity - No indications of mutagenicity were found for carbaryl in a dominant-lethal test with ICR-Ha Swiss mice (Epstein, et al., 1972). Negative results have also been reported in tests with the bacteria Bacillus subtilis (Degiovanni-Donnelly, et al., 1968) and Escherichia coli (Ashwood-Smith, et al., 1972).

In acidic media, carbaryl interacts with sodium nitrite to produce a potent mutagen, nitrosocarbaryl which is several fold more potent than nitrosomethylnitroguanidine, a commonly used positive control agent, in inducing mutations to prototrophy in a strain of E. coli requiring arginine. There is a probability that nitrosocarbaryl could be produced in the human stomach and thereby have significance as a mutagen in man (Elespuru, et al., 1973).

Carcinogenicity - Carbaryl has been extensively tested for carcinogenicity. All results obtained to date indicate that carbaryl is not a carcinogen. Several two-year studies have been conducted with rats and dogs and an 80-week feeding study with CD-1 mice (Union Carbide Corp., 1958a, b, 1973; Weil and Carpenter, 1972, 1965; Carpenter, et al., 1961; Innes, et al., 1969) but no increased incidence of tumors were found.

Reproduction/Teratogenicity - In rats, feeding studies with dosages up to 200 mg/kg/day of carbaryl revealed no effects on reproduction or on growth rate and micropathology of pups (Union Carbide, 1965). However, intubation with 100 mg/kg/day did show some decrease in the number of successful matings and the number of pups born alive (Union Carbide Corp., 1972).

High doses of carbaryl have been reported to affect embryonic development, survival and postnatal growth in some species. For example, rats fed carbaryl in their diet for three generations at levels of 2000, 5000 and 10,000 ppm showed effects at the highest dose; fertility was impaired, no litters were produced for the second mating of the second generation, survival of the progeny decreased and litter size declined (Collins, et al., 1977).

Guinea pigs administered 300 mg/kg/day carbaryl during pregnancy produced offspring with some birth defects but the dosage level employed was sufficient to produce mortality in 38% of the parents (Robens, 1969).

No teratogenic effects were found in rabbits, hamsters or rhesus monkeys exposed in various schedules to 200, 250 and 20 mg/kg/day carbaryl, respectively, during pregnancy (Robens, 1969; Coulston, 1973).

EFFECT ON BIRDS

Acute Toxicity - As indicated by the data shown in Table 1, the acute toxicity of carbaryl to test birds appears to be low. In one subacute study, the 30-day empirical minimum lethal dose (EMLD) was 125 mg/kg/day. Chronic studies show that large amounts, 370 mg/kg/day for 84 days, can cause "chronic effects" in quail (DeWitt and Menzie, 1971, as reported by USDA, 19).

Reproductive Effects - In three separate laboratory tests, carbaryl was injected directly into the yolk or allantoic cavity of developing chicken eggs. In all three studies, the carbaryl caused death (50% after injection of 3.44 mg/embryo) or malformations (after injection of 0.064 mg/kg and 50 ppm) (Tos-Luty, et al., 1975; Olefir and Vinogradova, 1968; Dunachie and Fletcher, 1969; all as reported by Sanborn, et al., 1977).

TABLE 1

TOXICITY OF CARBARYL TO BIRDS

	<u>LD₅₀ (mg/kg)</u>	
mallards	>2179	Tucker & Crabtree (1970)
Japanese quail	2290	Tucker & Crabtree (1970)
pigeons	1000 - 3000	Tucker & Crabtree (1970)
sharp tailed grouse	780 - 1700	Tucker & Crabtree (1970)
Canada geese	1790 (50% sample purity in test material)	Tucker & Crabtree (1970)

	<u>Five Day Dietary LC₅₀ (ppm)</u>	
bobwhite quail	>5000	USDI-BSFW (19)
Japanese quail	>5000*	USDI-BSFW (19)
pheasants	>5000	USDI-BSFW (19)
mallards	>5000	USDI-BSFW (19)

* 70% mortality at 5000 ppm.

In quail, "reproduction was reduced" after ingestion of a total of 12,000 mg/kg at a rate of 230 mg/kg/day. In pheasants, reproduction was reduced by 50% after inclusion of ≤ 500 ppm carbaryl in the diet before or during the breeding season (duration of dietary exposure not given) (DeWitt and Menzie, 1971, as reported by USDA, 19).

Field Studies - Numerous field observations of bird activity and reproduction have been made after application of carbaryl. Five such studies (McEwen, et al., 1972; USDA, 1964; Stitt, 1966; Connor, 1960; Studholme, 1972; all as reported by USDA, 19) detected no adverse effects of carbaryl application.* Two studies indicated some effect on nesting and feeding activity. One study by Wilcox (1972, as reported by USDA, 19) suggests a connection between the erratic weight patterns of young robins and carbaryl applications. Doane and Shaefer (1971) noted a decrease in bird activity (as measured by total hearings of 16 species) in a woodland in Connecticut after treatment with carbaryl. The decrease in bird activity was judged to be due to the severe decrease in the gypsy moth and other insects which comprised an important food source. Nesting and successful reproduction did not differ between treated and untreated plots. The authors suggest that applications of carbaryl over areas larger than the test plots (50 acres) might prevent access to food and alter nesting and other activity.

* Original literature must be consulted to determine the means for detection of 'harm' in these studies. Commonly, there is a great deal of variability in measurement anywhere from walking through an area after spraying to long term studies of specific nesting populations.

EFFECT ON OTHER TERRESTRIAL VERTEBRATES

Deer seem to be sensitive to carbaryl. For eleven-month-old mule deer the acute toxicity to carbaryl is 200 - 400 mg/kg LD₅₀ (Tucker and Crabtree, 1970). Johnson, 1971, as reported by USDA, 19 , stated that deer are six to ten times more sensitive to carbaryl than bird species but that field studies show no acute effects from normal application levels (USDA, 19). Chronic effects on deer are not known. Field observations of small mammals have not detected any harm in overall population numbers and activity* (Barret, 1968; Wilcox, 1972; both as reported by USDA, 19).

Carbaryl is not toxic to bullfrogs. The acute toxicity is >4000 mg/kg LD₅₀ using 50% sample purity in test material (Tucker and Crabtree, 1970).

EFFECT ON AQUATIC ORGANISMS

Fish

The effect of carbaryl on fish is unclear. The laboratory data, shown in Table 2, suggests that carbaryl can be considered moderately toxic to a number of species. As is usually the case, salmon is the most sensitive with LC₅₀ values of 0.76 and 0.99 ppm. Perch is also sensitive with an LC₅₀ value of 0.75 ppm. Rainbow, brown and cutthroat trout also appear to be sensitive.

*Original literature must be considered to determine whether any adverse effects were observed for individuals or groups within the 'population.'

TABLE 2

TOXICITY OF CARBARYL TO FISH

SPECIES	LC ₅₀ (ppm)	Time (hrs)	Conditions	Source
Fathead minnow (<u>Pimephales promelas</u>)	9.00 12.00	96 96	static	Carlson (NWQL - unpublished) ¹ Henderson, <u>et al.</u> (1960) ²
Bluegill (<u>Lepomis macrochirus</u>)	6.76 2.50 2.00 5.30	96 48 96 96	static static static static	Macek and McAllister (1970) ¹ Cope (1966) ² Cope (1965) ² Henderson, <u>et al.</u> (1960) ²
Largemouth bass (<u>Micropterus salmoides</u>)	6.40	96	static	Macek and McAllister (1970) ¹
Rainbow trout (<u>Salmo gairdneri</u>)	1.35 4.34 2.00	96 96 48	static static static	Katz (1961) ² Macek and McAllister (1970) ¹ Cope (1966) ²
Brown trout (<u>Salmo trutta</u>)	1.95	96	static	Macek and McAllister (1970) ¹
Coho salmon (<u>Oncorhynchus kisutch</u>)	0.76 0.99	96 96	static static	Macek and McAllister (1970) ¹ Katz (1961) ²
Yellow perch (<u>Perca flavescens</u>)	0.75	96	static	Macek and McAllister (1970) ¹
Channel catfish (<u>Ictalurus punctatus</u>)	15.80 19.00	96 48	static static	Macek and McAllister (1970) ¹ Cope (1966) ²
Black bullhead (<u>Ictalurus melas</u>)	20.00	96	static	Macek and McAllister (1970) ¹
Threespine stickleback (<u>Gasterosteus aculeatus</u>)	3.99	96	static	Katz (1961) ²

¹U.S. EPA, "Effects of Pesticides in Water, A Report to the States."²Battelle's Columbus Laboratories (for U.S. EPA), "Water Quality Criteria Data Book - Vol. 3 - Effects of Chemicals on Aquatic Life," 1971.

TABLE 2 (Continued)

TOXICITY OF CARBARYL TO FISH

	1.5 - 2.2	96	continuous flow	Post, et al. (1971) ³
Cutthroat trout (<u>Salmo clarki</u>)				
Goldfish (<u>Carassius auratus</u>)	13.20	96	static	Macek, et al. (1970) ³
Carp (<u>Cyprinus carpio</u>)	5.28	96	static	Macek, et al. (1970) ³

³Kemp, Homer T., R. Little, V. Holoman and R. Darby (For U.S. EPA), "Water Quality Criteria Data Book - Vol. 5 - Effects of Chemicals on Aquatic Life," 1973.

The available water residue data from previous gypsy moth programs (discussed in a later section) indicates that residues as high as 0.5 ppm can be found in ponds immediately after aerial application of one lb/active ingredient/acre of carbaryl.* One would expect, therefore, a few mortalities to occur among more sensitive species as a result of these previous applications. However, no mortalities were observed in monitoring activities in New Jersey, Pennsylvania and Massachusetts by USDA (1964) and in New Jersey by Wilcox (1964). Reports on these monitoring activities must be examined to determine if sensitive species were present at the time of application.

Two studies indicate that carbaryl may be eliminated rapidly from fish. Tompkins (1966, as reported by USDA, 19) claimed that 97% of ingested carbaryl was excreted by fish in eight hours (no species or data provided in review). Ishii and Hashimota (1970, as reported by Sanborn, et al., 19) found "complete degradation of carbaryl" (no 1-naphthol detectable) after 24 hours in carp. This rapid disappearance of carbaryl in fish is consistent with field study results but not with laboratory data shown in Table 2.

Carbaryl has been shown to be more toxic to fish when mixed in water than oil. Carbaryl is also more toxic in hard water than soft water. Finally, although fish do avoid a number of pesticides, they have been observed not to avoid carbaryl (Gould, 1972).

* As indicated later in the discussion of these residues, levels drop several orders of magnitude within days.

A number of authors have shown that 1-naphthol is more toxic to fish than carbaryl (Butler, et al., 1968; Lamberton and Claeys, 1970; and Stewart, et al., 1967, as reported by USDA, 19).*

Lower Aquatic Organisms

Both laboratory data and field tests indicate that reproduction in crustacea and molluscs are likely to be reduced by application of carbaryl. Table 3 shows the results of laboratory tests of carbaryl toxicity to a variety of aquatic invertebrates.

In field studies, reduction in aquatic invertebrate populations have been found in monitoring activities following gypsy moth suppression efforts with carbaryl in Pennsylvania and other states (USDA, 1964, as reported by USDA, 19). Stoneflies, mayflies, and dragonflies were mentioned as undergoing significant reduction. USDA (19) suggested that many marine shellfish species may also be reduced, especially since the 1-naphthol degradation product can form a more persistent precipitate in sea water and can be toxic to estuarine species (Lamberton and Claeys, 1970). Further investigation is necessary.

*Original data should be consulted in order to determine toxic concentrations.

TABLE 3

TOXICITY OF CARBARYL TO AQUATIC INVERTEBRATES

<u>SPECIES</u>	<u>LC₅₀ (ppm)</u>	<u>TIME (hrs)</u>	<u>CONDITIONS</u>	<u>SOURCE</u>
Amphipods (<u>Gammarus lacustris</u>)	0.016	96	static	Sanders and Cope (1969) ¹
Amphipods (<u>Gammarus fasciatus</u>)	0.026	96	static	Sanders (in press) ¹
Crayfish (<u>Orconectes nais</u>)	0.009	96	static	Sanders (in press) ¹
Isopods (<u>Asellus brevicaudus</u>)	0.24	96	static	Sanders (in press) ¹
(<u>Simocephalus serrulatus</u>)	0.008	48	static	Sanders and Cope (1966) ¹
Daphnia (<u>Daphnia pulex</u>)	0.006	48	static	Sanders and Cope (1966) ¹
Crayfish (<u>Procambarus clarki</u>)	2.00	72	static	Muncy and Oliver (1963) ²
Nymphs (<u>Pteronarcys sp.</u>)	0.005	96	static	Cope (1965) ²
Naiads (<u>Pteronarcys californicus</u>)	0.015 0.005	48 96	static static	Cope (1966) ² Sanders and Cope (1968) ¹

¹U.S. EPA, "Effects of Pesticides in Water, A Report to the States."²Battelle's Columbus Laboratories (for U.S. EPA), "Water Quality Criteria Data Book - Vol. 3 - Effects of Chemicals on Aquatic Life," 1971.

TABLE 3 (Continued)

TOXICITY OF CARBARYL TO AQUATIC INVERTEBRATES

Naiads (<u>Pteronarcella badia</u>)	0.002	96	static	Sanders and Cope (1968) ¹
Naiads (<u>Claasenia sabulosa</u>)	0.006	96	static	Sanders and Cope (1968) ¹
Grass shrimp (<u>Palaemonetes kadiakensis</u>) non-resistant	0.043	24	static	Nagvi, et al. (1970) ³
resistant	0.064 - 0.272	24	static	Nagvi, et al. (1970) ³
Grass Shrimp (<u>Palaemonetes kadiakensis</u>)	0.006	96	static	Sanders (in press) ¹
Hard clam (<u>Mercenaria mercenaria</u>) eggs	3.82	48	static	Davis, et al. (1969) ³
larvae	>2.50	14 days	static	Davis, et al. (1969) ³
Eastern oyster (<u>Crassostrea virginia</u>) eggs	3.00	48	static	Davis, et al. (1969) ³
larvae	3.00	14 days	static	Davis, et al. (1969) ³

¹U.S. EPA, "Effects of Pesticides in Water, A Report to the States."³Kemp, Homer T., R. Little, V. Holoman and R. Darby (for U.S. EPA), "Water Quality Criteria Data Book - Vol. 4 - Effects of Chemicals on Aquatic Life," 1973.

EFFECT ON PLANTS

Carbaryl has caused injury to MacIntosh and York varieties of apples and some pears along with watermelons and Boston Ivy. In regard to carbaryl, the pesticide manual warns that "excessive dosages may retard germination of grasses. Injury may occur on tender foliage in the presence of rain or high humidity for several days" (Thompson, 1976). Carbaryl can reduce fruit set in most varieties of apple trees when applied at rates of 0.5 to 2 lbs of active ingredient/100 gallons of spray.

Carbaryl apparently increases the persistence of the herbicide chloropham and increases the herbicidal activity (phytotoxicity) of the herbicide dalapon. Carbaryl increases the persistence of chloropham by interfering with microbial degradation of this chemical (Guenzi, 19).

EFFECT ON BENEFICIAL INSECTS

Carbaryl is known to be "highly toxic to bees" (Thompson, 1976). (No reliable acute toxicity data was immediately available.) Carbaryl also appears to be toxic to earthworms. In a pasture, the biomass of earthworms was reduced by 60% (their numbers, by 68%). In another study, the reduction in earthworms by carbaryl delayed straw decomposition by 6.5 to 17.6%. No application rates were stated in the discussion of either study (Thompson, 1970; and Atlavinyte, et al., 1975; both as reported by Sanborn, et al., 19). In another study, carbaryl applied at two lbs/acre of a wettable powder formulation resulted in a 59.8% decrease in earthworm numbers (Thompson, 1971, as reported by USDA, 19). Carbaryl is also toxic to predator beetles, Calosoma frigidum and C. sycophanta (Doane and Shaefer, 1971). Carbaryl also appears

to be toxic to an egg parasite, Ooencurtis rumanai (Sellmer and Syngg, 1973, as reported by USDA, 19).

FATE IN SOIL, WATER AND PLANTS

Carbaryl has been reported to have a half life of eight days in the soil. It is degraded by soil microorganisms to 1-naphthol which is further degraded to a series of intermediate products and finally to 1,2 dihydroxybenzene and pyrovic acid. 1-Naphthol is "more toxic and more persistent than carbaryl" (Kaufman, 1974; and Bollag and Liu, 1971; both as reported by Sanborn, et al., 19). Adsorption on kaolinite and bentonite is minimal* (Gould, 1972). However, carbaryl is strongly adsorbed to humic substances (Kazano, et al., 1972, as reported by Guenzi, et al., 19) a substance commonly found in the thin surface organic layer usually present in Massachusetts forest soils.

The one study found on leaching potential of carbaryl suggests some downward movement. For 15 to 20 days after applying 1000 l/ha of 3% carbaryl, residues (no amounts given) were detected at depths of 50 to 60 cm (Nalbandyan, 1974, as reported by Sanborn, et al., 19).

Carbaryl hydrolyses in neutral and alkaline waters (beginning at pH 7) to form 1-naphthol. The rate of hydrolysis increases with increasing pH (Gould, 1972). The fate of 1-naphthol was studied by Bollay, et al. (1975) (as reported by Sanborn, et al., 19).

Radiolabelled 1-naphthol was added to bacterial culture growing on

* Illite is the type of clay more commonly found in Massachusetts than either kaolinite or bentonite. However, these latter two are stronger adsorbents generally than illite and thus it is likely that carbaryl adsorption on illite is also minimal.

river water based mediums. Within 60 hours, 44% of the radioactive carbon was released as carbon dioxide, 17% remained in the growth medium and 22% became associated with the bacteria. The major residue in the growth medium was 4-hydroxy-1-tetralone. When the bacteria were exposed to greater than 100 ppm 1-naphthol, growth was inhibited.

Three studies are available which examine the disappearance of carbaryl residues in ponds. These studies (as presented by USDA, 19) measure only the disappearance of carbaryl and not 1-naphthol. In New Jersey ponds, residues of carbaryl were 0.030 ppm immediately after spraying, dropping to 0.0015 ppm the next day and 0.0010 ppm after six days (USDA, 1964). No application rate was included in the discussion of this study. In another study, residues from a one lb. active ingredient/acre treatment of carbaryl resulted in an initial residue of 0.5 ppm. At day four, the residues were ≤ 0.05 ppm and at day eight between 0.01 and 0.02 ppm (Romine, 1971). One of the "sinks" for carbaryl may be bottom sediments. After eight days, the maximum level which had been found in bottom sediments was 0.62 ppm, while the maximum in water was 0.05 ppm (Devine, 1971).

In plants, metabolism may simply inactivate the carbaryl or degrade it through oxidation or hydroxylation of the N-methyl group followed by ring degradation (Kuhr, 1968). Carbaryl may be more persistent in plants than either soil or water. A user's manual states that "control should last for one to three weeks" (Thompson, 1976). Tests have shown that when broccoli, spinach, tomatoes and green beans are washed and blanched, 50% of carbaryl residues remain ().

Carbaryl may undergo photodegradation yielding some products which are also cholinesterase inhibitors (Crosby, et al., 1965, as reported by Sanborn, et al., 19 __. Further investigation of this possibility is necessary.

CARBARYL (SEVIN[®])

Effects on humans and laboratory mammals:

Carbaryl shows moderate toxicity to laboratory mammals. However, there is no evidence of harm to humans from occupational exposure. Carbaryl has been shown to be readily metabolized in test mammals. In regard to long-term effects, there is some evidence to suggest that in the human stomach, carbaryl could react with sodium nitrate (found in some foods) to form nitrosocarbaryl which has shown to be a potent mutagen in laboratory tests. Teratogenic effects of carbaryl have also been suggested in laboratory tests on dogs.

Effect on birds:

The acute toxicity of carbaryl to test birds is low. However, there is evidence to suggest that carbaryl may impair the reproductive ability of test birds. Also, field tests show that carbaryl may decrease available food for birds thus altering feeding activity. Nesting activity does not appear to be affected by carbaryl (at least in 50 acre test plot applications).

Effect on aquatic organisms:

Indications provided by field tests and laboratory tests on the effects of carbaryl on fish are inconclusive. Further investigation of the literature is particularly important in this regard. In regard to lower aquatic organisms, both field and laboratory tests indicate that carbaryl causes a reduction in some aquatic invertebrate populations.

Other effects:

Carbaryl appears to be acutely toxic to deer. Chronic effects on deer have not been studied. Phytotoxic effects of carbaryl have been shown to occur in some varieties of apples, pears, and watermelons. Boston ivy and some grasses may also be harmed by carbaryl.

Carbaryl appears to be toxic to a number of beneficial insects. It is highly toxic to bees. It also appears to be toxic to earthworms and a number of beneficial predators (which are capable of controlling pest populations).

Fate in soil and water:

Carbaryl has a short (eight day) half-life in soil. Microorganisms degrade it to simpler hydrocarbons. However, one of the intermediate products is said to be more toxic and more persistent than the original compound. Mobility of carbaryl in the soil is unclear although it is likely to be retained by adsorption in surface organic layers, and also move downward to some extent through leaching.

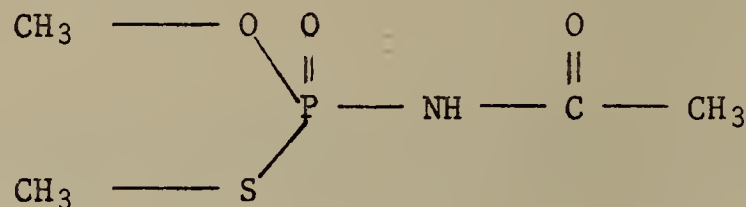
In water, carbaryl degrades more slowly than in soil. Again, one of the intermediate degradation products is more toxic and more persistent than the original compound and has been shown to be particularly toxic to estuarine species.

The following draft is the result of a preliminary investigation of immediately available literature examined over a one month period.

ACEPHATE (ORTHENE[®])

GENERAL INFORMATION

Acephate is an organophosphate compound used as a contact and systemic insecticide. It is a white solid with the following chemical structure:



O,S-dimethyl acetylphosphoramidothioate

Acephate has a low volatility (although some of its degradation products are relatively volatile) and extremely high solubility in water (more detail provided later). It is also soluble in alcohol (25%) and methylene chloride (30%). It has low solubility in aromatic solvents such as benzene (1%).

MAMMALIAN TOXICOLOGY

Acephate appears to have a low mammalian acute toxicity as indicated by an oral LD₅₀ in rats of 945 mg/kg for males and 866 mg/kg for females (Chevron, 19). Its dermal toxicity also appears low: the dermal LD₅₀ in rabbits is >2000 mg/kg (Chevron, 19). The following is taken from the manufacturer's literature:

"Feeding studies show that Orthene is rapidly eliminated by mammals and birds and is not retained in body tissues. Orthene does not have long-term toxic effects, and does not significantly affect reproduction or the health of succeeding generations. No mutagenic, teratogenic or tumorigenic effects were noted in these studies....In vitro studies indicate that acephate is a weak acetylcholinesterase inhibitor...."

No published data are available to substantiate or refute these claims. The one exception is a study on the potential mutagenic effect of acephate. Hanna and Dyer (1975) tested the mutagenic activity of Orthene-755[®] in two bacteria, Salmonella typhimurium and Escherichia coli. (The bacterium Salmonella typhimurium yields information regarding the molecular nature of the mutation such as base-pair substitution or frameshift mutations while tests with E. coli distinguish mutagens which alter DNA and cause mutations by "error-prone" repair systems with the cell.) In a spot assay test employing various strains of these two bacteria, addition of 5-10 µl of Orthene-755[®] produced negative responses in four strains of S. typhimurium (his C 117, his G 46, TA 1530, TA 1535) which detect base-pair substitutions. Positive indications of mutagenic activity were observed, however, in four studies of E. coli (WP 2, WP 2 uvr A, WP 67, WP 12).

EFFECT ON BIRDS

Acute Toxicity - Acephate appears to be somewhat toxic to test birds, as indicated by the following acute toxicity data from the manufacturer's experimental data sheet (Chevron, 19)::

Mallards	350 mg/kg LD ₅₀
Ring necked pheasants	140 mg/kg LD ₅₀
Chickens	852 mg/kg LD ₅₀
Bobwhite quail	222 mg/kg LD ₅₀ using a 50% acephate material

In a field test, acephate applied at rates greater than 0.140 kg/ha was found to be harmful to a "small forest bird complex" but showed no effect at a rate of 0.070 kg/ha (Buckner, et al., abstract, 19). Indications of harm were not included in the abstract.

EFFECT ON AQUATIC ORGANISMS

Fish

Acephate appears to be "relatively non-toxic to fish" (Thompson, 1976), as suggested by the following data from the manufacturer's experimental data sheet (Chevron, 19):

Rainbow trout	>1000 ppm	96 hr. TL ₅₀
Blue gill	>2050 ppm	96 hr. TL ₅₀
Large blackmouth bass	1725 ppm	96 hr. TL ₅₀
Channel catfish	2230 ppm	96 hr. TL ₅₀
Mosquito fish (<u>Gambusia</u>)	6650 ppm	96 hr. TL ₅₀
Goldfish	9550 ppm	96 hr. TL ₅₀

Lower Aquatic Organisms

The only information immediately available concerns the effect on Rana clamitans tadpoles. Acephate has been observed to affect the tadpoles behavior, specifically its swimming behavior, bubble making, resting position and color. In an aquatic ecosystem residual levels of acephate in tadpole tissues approximated ambient levels present in the water medium (Lyons, et al. - abstract, 19).

EFFECT ON BENEFICIAL INSECTS

Acephate is highly toxic to bees if the bees come in contact with residues on crops or if exposed by direct application (manufacturer's specimen label). USDA assessed acephate's toxicity to bees as "slightly higher than carbaryl" (USDA, 19). Acephate appears to be toxic to a number of beneficial insects. Manufacturer's literature states that "Orthene[®] will reduce populations of beneficial insects present at the time of application," although it apparently does not harm Chelonus blackburni and Crysopa garnea (lace wings) (Chevron, 19).

PHYTOTOXICITY

Foliage injury may occur to American elm, flowering crab sugar maple, cottonwood and huckleberry (Chevron, specimen label). At a rate of 0.5 to 1.0 lb/100 gallons water, acephate produces a marginal leaf burn on red delicious apple trees (Chevron experimental data sheet).

FATE IN SOIL WATER AND PLANTS

In soil, acephate is degraded by microorganisms and has a short half life of 0.5 to 8 days in a variety of soil types (Chevron, 19). Residues in leaf litter dropped below the 0.02 ppm limit of detection within 33 days after aerial application of 1/2 lb/acre (Wilcox, 1973, as reported by USDA, 19).

In water, acephate breaks down slowly since it does not hydrolyze readily. At a pH of 5-7 the half life is about 50 days at 21°C and 20 days at 40°C (Chevron literature, 19).

Acephate is highly soluble in water (65%)* (Chevron literature, 19). Although no supportive information was found, this high solubility suggests that:

- Acephate may be mobile in soil moving vertically and laterally with rainfall and evaporation.
- Acephate in water may not be bound to suspended material and sediments as are most other pesticides.
- Acephate is not likely to accumulate in organisms (substances which have high water solubility and low solubilities in organics generally are not concentrated in tissue).

In plants, 90-95% of acephate degrades directly to "innocuous salts." The other 5-10% is converted (by photodegradation) to methamidophos (O,S-dimethyl phosphoramidothioate), the active ingredient of a closely related insecticide, Monitor[®] (Szeto, et al. - abstract). The only information immediately available on methamidophos states that it is "toxic to birds and other wildlife....Toxic to bees" (Thompson, 1976).** Standard compilations of published information on the effects of pesticides unfortunately do not include information on the effects of methamidophos. Further investigation is necessary.

* 65% in water could mean any of the following: 65 gms or 65 cc's of acephate dissolving in 100 gms or 100 cc's of water or 65 gms or cc's of acephate dissolving in 100 gms or cc's of total orthene and water solution.

** This source contains information usually extracted from manufacturer's literature.

ACEPHATE (ORTHENE®)

Effect on laboratory mammals:

In regard to short-term effects, acephate appears to have a low mammalian acute toxicity and dermal toxicity. Regarding long-term effects, insufficient information is available to judge the potential for teratogenic and carcinogenic effects, although some information was available to suggest that acephate may have some mutagenic activity in some species of bacteria.

Effect on birds:

Acephate appears to be somewhat toxic to test birds. The limited field information available suggests that some adverse effects can occur. Further investigation of this literature is necessary.

Effect on aquatic organisms:

Acephate appears to be relatively non-toxic to fish. Insufficient information is available to assess the effect of acephate on aquatic invertebrates.

Fate in soil and water:

In soil, acephate is degraded by microorganisms and has a short half-life of one-half to eight days in a variety of soil types. Degradation in water is slower with a half-life of 20 to 50 days, depending on temperature.

The high solubility of acephate in water may increase its mobility in soil, decrease the likelihood of bioaccumulation in aquatic organisms.

In plants, 90 to 95% of acephate is degraded to innocuous salts. The rest is converted to methamidophos which is reported to be toxic to birds and other wildlife and toxic to bees. Further investigation is necessary.

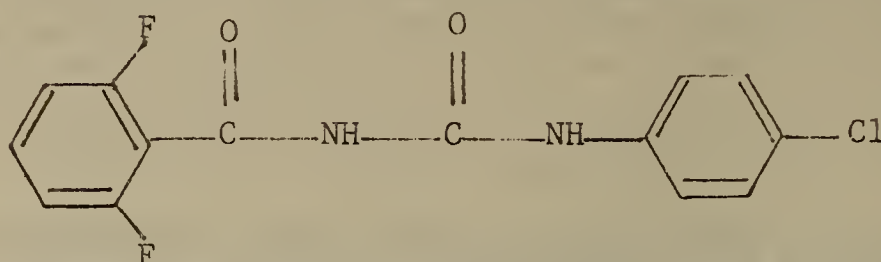
Other effects:

Acephate is highly toxic to bees and a number of other beneficial insects. Also, foliage injury may occur to American Elm, flowering crab, sugar maple, cottonwood, huckleberry, and red delicious apple trees.

The following draft is the result of a preliminary investigation of immediately available literature examined over a one month period.

DIFLUBENZURON (DIMILIN[®])

Diflubenzuron, also called Dimilin[®], difluron, and TH-6040, is a chlorinated diphenyl compound with the following structure:



N(((4-Chlorophenyl)amino)carbonyl)
-2,6-difluorobenzamide

As an insecticide, it interferes with the formation of insect cuticle causing developing larvae to rupture the malformed cuticle or die of starvation. It is a white crystalline solid with very low water solubility (approximately 1 ppm). Its solubility in polar solvents and apolar solvents is moderate and low, respectively. It is stable in water between pH 2 and 8, unstable at pH 12 (Thompson-Hayward, 1972).

MAMMALIAN TOXICOLOGY

A single oral dose (1 mg) of radiolabelled-diflubenzuron was readily excreted in the urine (17%) and feces (61%) of female rats within 24 hours of administration. By six days, 92% of the administered radioactivity had been recovered (22% in urine; 70% in feces). The major urinary metabolite was difluorobenzoic acid (CAG, 1978). Another metabolite, 4-chloroacetanilide, has been identified in the liver, urine and milk of cows (CAG, 1978).

With respect to the mammalian toxicity of diflubenzuron, the Carcinogen Assessment Group's Preliminary Report on Dimilin[®] (CAG, 1978) states that no signs of toxicity, mortality or other abnormalities have

been observed with diflubenzuron in several unpublished acute and sub-chronic studies at doses below 10,000 mg/kg in mice and 20,000 mg/kg in rats. Rats exposed to 0.5, 5.0 or 50 mg/l of diflubenzuron dust daily for one hour, five days per week for three weeks did show treatment related increases in spleen weight, however (CAG, 1978).

There is no evidence of mutagenic activity with diflubenzuron in the Ames test but positive findings have been recorded for the metabolites 4-chloroaniline and 2,6-difluorobenzoic acid. Test concentrations and strains of Salmonella typhimurium used were not given (CAG, 1978). Negative results have also been reported with diflubenzuron in the yeast, Saccharomyces; in a mouse micronucleus test; in unscheduled DNA synthesis in mammalian cells and in dominant lethal test (CAG, 1978).

An adequate assessment of the carcinogenicity of diflubenzuron is not available. Only one unpublished study conducted with rats and mice has been completed; the results of this proprietary study were presented in the Carcinogen Assessment Group's Preliminary Report on Dimilin[®] (CAG, 1978) and indicated a dose-related increment in the incidence of lymphoreticular tumors (lymphosarcomas, reticulum cell sarcomas, myeloid leukemia) in female CFLP mice fed 4-50 ppm diflubenzuron in the diet for 80 weeks. No carcinogenic effect was noted in Sprague Dawley rats fed up to 160 ppm diflubenzuron in the diet for 104 weeks but the results were complicated by poor survival (>35% at 104 weeks). More importantly, several limitations in experimental protocol and in the interpretation of data suggests serious

questions about the reliability of these experiments. For example, no information was provided to indicate whether the diet was chemically analyzed at any time during the study to determine the actual concentration. In addition, the maximum tolerated dose was selected based upon results of a six week subacute study conducted with male mice and based solely on liver pathology. Other organs and tissues were not examined raising serious doubts as to whether the highest dose tested was too low to assure a definite and significant carcinogenic effect (CAG, 1978).

Another issue in the evaluation of the carcinogenicity of diflubenzuron in mice is that only seven tissues (lymph nodes, spleen, liver, thyroids, ovaries, adrenals and pituitary glands) were routinely examined histopathologically. The lungs, kidneys, heart and testes were not examined. Furthermore, in a reassessment of the histopathology of mouse lymphoreticular tissue by the same laboratory, some tissues reported as autolysed in the first report were reportedly examined histopathologically for the reassessment (CAG, 1978).

These severe limitations of the one available chronic study leave the question of the carcinogenicity of diflubenzuron unresolved. A preliminary report from the National Cancer Institute (CAG, 1978), however, indicates that parachloraniline, a metabolite of diflubenzuron is carcinogenic in both rats and mice.

EFFECT ON BIRDS

Acute Toxicity - The following data suggest the acute toxicity of diflubenzuron to test birds is low:

Bobwhite quail:	>5000 mg/kg LD ₅₀	(Cannon, 19) [*]
Mallards:	>5000 mg/kg LD ₅₀	(Cannon, 19) [*]
Red winged blackbirds:	3762.6 mg/kg LD ₅₀	(Bioscientific, 19) [*]
Bobwhite quail:	>4640 ppm 8 day dietary LC ₅₀	(Thompson-Hayward, 1974)
Mallards:	>4640 ppm 8 day dietary LC ₅₀	(Thompson-Hayward, 1974)

Reproductive Effects - Three studies have been done on reproductive effects of diflubenzuron on bobwhite quail. One study showed no effect in egg production, fertility or hatchability (Booth, 19)^{*}. Another study, however, showed a decrease in egg production at 250 ppm in the diet (Cannon, 19)^{*}. The third study shows a decrease in egg production at 40 ppm; however, the control bird egg production was somewhat lower than usual (Cannon, 19)^{*}.

The effect of diflubenzuron on reproductive steroid hormones is unclear. Tests for the effect of diflubenzuron are serum testosterone levels in chicken, bobwhite quail, mallard ducks, ring necked pheasants and turkeys show highly variable, conflicting results (Smalley, 1977, Cecil, 1977)^{*}. Similarly, tests for the effect of diflubenzuron on serum estrogen in chickens and bobwhite quail are also unclear due to conflicting results and problems in testing (Smalley, 1977)^{*}.

Tests on growth and weight changes in bobwhite quail, mallards, ring necked pheasants, turkeys, and chickens show no adverse effect of diflubenzuron on growth and weight changes (Cannon, 19 ; Phillips, 19 ; Smalley, 1977; Roxanne, 19 ; and Cecil, 1977)^{*}.

^{*}As reported by USDA, 1978.

EFFECT ON AQUATIC ORGANISMS

Fish

Acute Toxicity - Dimilin appears to be somewhat toxic to test fish. The 96 hour LC₅₀ data as reported by the manufacturer's literature (Thompson-Hayward, 1974) are:

Bluegill sunfish [*]	135 ppm	technical material 25% wettable powder (WP) formulated material
Rainbow trout [*]	140 ppm 195 ppm	technical material 25% WP
Saltwater minnow [*]	255 ppm	25% WP
Channel catfish [*]	180 ppm	25% WP

Bioaccumulation in Fish - It appears that bluegill sunfish, Lepomis microchirus, white crappies, Pomoxis annularis, and black crappies, Pomoxis nigromaculatus, are able to concentrate diflubenzuron at levels up to 80-fold within 24 hours. The amount bioaccumulated appears to be proportional to the concentration in the water, i.e., as the concentrations of diflubenzuron increase or decrease in water, the concentrations in fish tissues increase or decrease. When water levels drop to below detectable limits, fish tissue residues also decline to below detectable limits. The degradation products in rainbow trout and bluegill sunfish have been shown to be primarily 4-chloroaniline with some 2,6-difluorobenzoic acid and 4-chlorophenylurea. (Anderson, et al., 1978; Shaefer, et al., 1978; Colwel and Shaefer, 1978; all as reported by USDA, 1978).

^{*} No species name given: Lepomis machrochirus, Salvo gairdneri,
, and are assumed.

Lower Aquatic Organisms

Much of the concern about diflubenzuron focuses on its potential effect on lower aquatic organisms. Acute toxicity and reproductive effects appear to be of primary concern.

Acute Toxicity - As shown by Table 1, the toxicity of diflubenzuron to aquatic invertebrates ranges from extremely toxic to relatively non-toxic, depending on the species. The low LC_{50} values for tadpole shrimp, clam shrimp, Daphnia and Gammarus, suggest that population reductions could result from very low concentrations in water (e.g., 0.0004 ppm for clam shrimp) (Miura and Takahashi, 1974, as reported by USDA, 1978). This is particularly important in light of exposure estimates made by an EPA/USDA state task force (1978). They calculated concentrations of diflubenzuron that could be expected after application of 0.125 lb. diflubenzuron per acre assuming six inches of water, direct application to exposed water bodies and no adsorption onto sediments. By their calculations, 0.1 ppm would be the expected concentration, given an oil based formulation, or 0.067 ppm given a water based formulation. For gypsy moth control, the rates of application of diflubenzuron range from 0.0312 to 0.125 lb. of active ingredient. Assuming a linear relationship between application rate and resultant exposure, the expected concentration range would be 0.025 to 0.1 ppm for oil based formulation and 0.016 to .067 ppm for water based formulation. Adsorption to suspended material would decrease the concentration in water (although adsorbed diflubenzuron would continue to be a source of exposure for many aquatic organisms).

TABLE 1
ACUTE TOXICITY OF DIFLUBENZURON
TO AQUATIC INVERTEBRATES

	<u>LC</u> ₅₀ ppm	
clam shrimp	0.0006 (24 Hr)	Miura & Takahashi* (1974)
tadpole shrimp	0.0004 (24 Hr)	Miura & Takahashi* (1974)
<u>Daphnia</u>	0.018 (48 Hr)	Miura & Takahashi* (1974)
<u>Gammarus</u>	0.04 (48 Hr)	Sanders & Julin* ()
dragonfly	0.05 (7 Day)	Miura & Takahashi* (1975)
hydrophilids	0.1 (48 Hr LC ₃₀)	Miura & Takahashi* (1975)
seed shrimp	5.0 (24 Hr)	Miura & Takahashi* (1974)
copepods	10.0 (24 Hr)	Miura & Takahashi* (1974)
oysters 4 day old larvae	130 (25% formulation Thompson-Hayward 96 Hr LC ₅₀)	(1974)
juveniles	250 (25% formulation Thompson-Hayward 96 Hr LC ₅₀)	(1974)

* As reported in USDA, 1978.

Field studies confirmed that some species will be severely reduced by low concentrations of diflubenzuron. Table 2 shows aquatic invertebrates which showed greater than 33% reduction in population at concentrations of 0.03 ppm or less of diflubenzuron. Daphnia appears to be very sensitive to diflubenzuron in these field studies. In one study, a greater than 99% reduction occurred at a concentration of 0.003 ppm.

Reproductive Effects^{*} - There is evidence to suggest that diflubenzuron can, temporarily at least, reduce the reproductive capacities of aquatic organisms. In a letter to USDA, EPA stated that data was available suggesting the potential for reproductive inhibition of mysids, black swimmers, tadpole shrimp, Daphnia, mayfly nymphs, chironomid midge larvae, copepods and amphipods. In laboratory tests by Mulla, et al. (1975), the reproduction of water fleas was observed to be suspended for one week after exposure to diflubenzuron, while some notonectidae were observed to suspend reproduction for more than two months after treatment (Miura and Takahashi, 1974). No information on the concentration of diflubenzuron was given. One test (Nimmo, 1978) found reproduction to be decreased about 40% at 0.07 ug/l diflubenzuron. Because of the current levels of detection of diflubenzuron, noted in the same study as 400 ppt, there is some question of the actual amount of exposure to the test population. A USDA (1978) review of this study indicated that reproductive effects begin at some point between 0.2 and 0.6 ppb. Another study (Cunningham, 1976) showed significant reduction in brine shrimp reproductive life span in adults exposed to 2, 5, and 10 ppb concentrations.

^{*} All citations as reported by USDA (1978).

TABLE 2

FIELD TESTS
EFFECT OF DIFLUBENZURON ON AQUATIC INVERTEBRATES

<u>Organism</u>	<u>Concentration (PPM)</u>	<u>% Reduction</u>	<u>Source*</u>
<u>Daphnia</u>	0.003	+ 99	Apperson <u>et. al.</u> , 1978
copepods	0.013	50	Colwell & Shaefer, 1977
<u>Daphnia</u>	0.013	+ 99	Colwell & Shaefer, 1977
<u>Daphnia</u>	0.03	+ 90	Miura & Takahashi, 1975
dragonfly	0.03	33 - 50	Farlow <u>et. al.</u> , 1978 - Steelman, 1975
notonectids	0.03	67	Farlow <u>et. al.</u> , 1978
copepods	0.03	47 - 60	Apperson <u>et. al.</u> , 1978
corixidae	0.03	40	Farlow <u>et. al.</u> , 1978
<u>Hyallella azteca</u>	0.03	57	Farlow <u>et. al.</u> , 1978
mayflies	0.03	50 - 64	Miura <u>et. al.</u> , 1975 Mulla <u>et. al.</u> , 1975

* All as reported by USDA, 1978. No explanation why so many separate tests resulted in 0.03 ppm under field conditions. Original data must be consulted.

FATE IN SOIL AND WATER

Degradation and Persistence in Soil - The persistence of diflubenzuron in soil appears to be highly variable. Manufacturer's literature reports the half life in soil to be about two months (Thompson-Hayward, 1972). USDA (1978) reports the half life of diflubenzuron in soil (with a particle size of about two microns) to be one-half to one week. About a ten-fold increase in persistence occurs when particle size is increased to ten microns (Nimmo and deWilde, 1975, as reported by USDA, 1978). Manufacturer's literature indicates that the particle size of diflubenzuron in commercial wettable powder formulations is less than five microns.

The formulation also appears to affect the persistence of diflubenzuron. Application as an acetonic solution as opposed to an aqueous solution severely decreases the amount of degradation of diflubenzuron in soil. In one study only minimal degradation of diflubenzuron was observed after four weeks in soil (Metcalf, et al., 1975, as reported by USDA, 1978).

The mechanism of degradation is microbial with principal degradation products being 2,6-difluorobenzoic acid and 4-chlorophenylurea.

(Another product 2,6-difluorobenzamide is sometimes intermediate in the formation of 2,6-difluorobenzoic acid.) The half lives of the two primary degradation products, 4-chlorophenylurea and 2,6-difluorobenzoic acid, are two to three weeks and four weeks, respectively, indicating a further rapid degradation. Eventually, one degradation product appears to be carbon dioxide; approximately 28% of radiolabelled carbon from the parent compound evolved as carbon dioxide after 91 days in soil (Nimmo and deWilde, 1975, as reported by USDA, 1978).

Photodecomposition - Although diflubenzuron degrades under artificial light in the laboratory to a variety of photo products, natural sunlight exposure in the field has shown diflubenzuron to be photochemically stable (Bull and Ivie, 1978, as reported by USDA, 1978).

Persistence in Water - Diflubenzuron in water is adsorbed onto organic matter and other particulates. It is also hydrolyzed to 4-chlorophenylurea and 2,6-difluorobenzoic acid. The half life of diflubenzuron in water ranges from 1 to 15 days depending on a variety of factors including pH (diflubenzuron hydrolysis occurs more rapidly in alkaline water) (Nimmo and deWilde, 1975, as reported by USDA, 1978).

Plants - Diflubenzuron is persistent on foliage of treated and non-target plants. When applied, it adheres to leaf surfaces and is not readily lost due to volatilization or photodecomposition if leaf penetration does occur. Residues of diflubenzuron can be taken up by plants from soil. Small amounts (less than 0.05 ppm) of diflubenzuron or its metabolic products may accumulate in seeds of some exposed plants (Bull and Ivie, 1978, Mansager and Still, 1978, and Gustafson, et al., 1976, all as reported by USDA, 1978).

Diflubenzuron is considered non-phytotoxic at recommended rates (Thompson, 1976). The manufacturer reports no phytotoxic effects in tests up to 10,000 ppm spray concentration (Thompson-Hayward, 1972).

DIFLUBENZURON (DIMILIN[®])

Effect on laboratory mammals:

In regard to short-term effects, the acute mammalian toxicity, both acute and subchronic, appear to be low. Diflubenzuron is readily excreted within 24 hours of administration to test mammals. In regard to long-term effects, there is no evidence of mutagenic activity with diflubenzuron, but some indications of mutagenic activity have been recorded for two of its metabolites.

An adequate assessment of the carcinogenicity of diflubenzuron is not available due to the inadequate test procedures used in studies to date. A preliminary report from the National Cancer Institute, however, indicates that one of the metabolites of diflubenzuron is carcinogenic in both rats and mice.

Effect on Birds:

The acute toxicity of diflubenzuron in test birds is low. There are some indications that diflubenzuron may reduce egg production in bobwhite quail and affect the reproductive steroid hormones in a number of test birds. However, in both cases the results are unclear due to conflicting evidence and problems in testing.

Effect on aquatic organisms:

Diflubenzuron appears to be somewhat toxic to test fish. Fish are apparently also able to concentrate diflubenzuron at levels up to 80-fold within 24 hours. However, the concentration of diflubenzuron in fish tissues decreases with decreases in water concentration and when water levels drop to below detectable limits, fish tissue residues also decline to below detectable limits.

Diflubenzuron is extremely toxic to a few aquatic invertebrates, and toxic to a number of others. Calculated exposure levels, assuming hypothetical concentrations applied to hypothetical water bodies, indicate a number of aquatic invertebrate populations may be reduced. Field studies have shown that this population reduction occurs after application for gypsy moth control.

Diflubenzuron can, temporarily at least, reduce the reproductive capacities of aquatic organisms such as tadpole shrimp, mayfly nymphs, copepods and amphipods.

Fate in Soil and Water:

The persistence of diflubenzuron in soil appears to be highly variable with a half-life ranging from one-half week to two months. The mechanism of degradation is microbial.

In water, diflubenzuron is adsorbed onto organic matter and other particulates. The half-life ranges from one to fifteen days, depending on a variety of factors including pH.

Other effects:

Diiflubenzuron is considered non-phytotoxic at recommended rates. No information is immediately available on the effects of diiflubenzuron on beneficial insects.

C. Integrated Pest Management

"The presence of toxic chemicals in our environment is one of the grimmest discoveries of the industrial era. Rather than coping with these hazards after they have escaped into our environment, our primary objective must be to prevent them from entering the environment."

President Carter, in his
Environmental Message

Integrated pest management is in keeping with President Carter's wishes. It is a control method which uses both natural and artificial means for reducing pest populations to acceptable levels. IPM relies less on chemicals than have most control efforts undertaken during the last thirty to thirty-five years. Although the term "Integrated Pest Management" is new, its practice has a long history. Its use in gypsy moth control dates to the early 1900's, when the Federal Government and the Commonwealth undertook a program of importing parasites and predators. However, with the advent of DDT use in the 1940's, most control programs focused on chemical spraying of extensive areas. There was even hope of eradicating the gypsy moth.

Because these efforts failed to contain the gypsy moth, and because of increased awareness of the adverse effects of massive chemical spray programs, the United States Department of Agriculture, Forest Service, in its Cooperative Gypsy Moth Suppression and Regulatory Program, now advocates IPM, reserving control efforts for "high use, high value areas, and high value forests". Other areas are left unsprayed in order to serve as reservoirs for the gypsy moth parasites and predators. (15)

The above as advocated by the U.S. Forest Service, has been the practice of the Department of Environmental Management since issuance of the "policy" in 1974. Part of that policy is as follows:

A Policy Related to People Rather than the Deep Forests

1. The Department of Natural Resources will direct its efforts towards alleviating the nuisance to people created by this pest.
2. The Department shall continue, through aerial and ground surveys, to determine the extent of infestation and population levels.
3. This information shall be given to the local superintendent of insect pest control in the various communities.
4. From this information it shall be the responsibility of local officials to determine the need for control and the location in the community where control measures shall take place.
5. Priority generally shall be given to roadsides, residential areas and recreation areas.
6. Technical help will be provided by personnel of the Department of Natural Resources in the determination as to the insecticide best suited for the purpose, the timing of the application and the method of application.
7. All work shall be done under the general supervision of the Chief Superintendent in accordance with Chapter 132, Section 13, general laws.

The decreased reliance on chemicals has numerous benefits:

1. Economic advantages. Both the chemicals and their application are becoming more costly. This will become increasingly significant as the price of petrochemicals continues to rise.
2. Less chance of the pest developing resistance to pesticides.
3. Reduced adverse effects on parasites and predators.
4. Fewer problems with secondary pests (i.e. mites, aphids, scale).
5. Reduced effects on other non-target species.
6. Less chance of chemical contamination of food, soil, and water.
7. Less chance of harmful human exposure to pesticides.

IPM in many cases can achieve results equal to, or in some cases even superior to, methods relying solely on chemicals. For instance, natural controls can do an excellent "mop-up job" of an outbreak. When a caterpillar is killed by a chemical, its death is a dead-end. When killed by natural

Summary of Materials and Methods Considered for Gypsy Moth Control

Material or Method	Rate Per Acre	Efficacy	Consistency of Results	Cost Per Acre (Aerial)	Ease of Application	Availability	Generally Viable Alternative-1979	Comments
Inundative release of parasites		0-25%	?	High	Difficult	Need facilities to rear	No	
Establish new species of parasites		Varies	Continuous if established	Moderate	Simple	Only to governmental agencies	No	On going programs in Mass.
Gypchek	* 2 applications	Erratic	Erratic	High	Simple	Only to governmental agencies	No	
Bacillus thuringiensis	1 pound twice	51-75%	Erratic	\$13.50 (1978)	Simple	Yes	Yes	
Disparure	?	?	?	?	Simple	No	No	Effective only in low populations
Sterile male release		?	?	High	Difficult	Need facilities	No	On going research
Carbaryl	1 pound	76-100%	Good	\$3.50 (1978)	Simple	Yes	Yes	Refer to chart on toxicology
Dylox	1 pound	76-100%	Good	\$5.50	Simple	Yes	Yes	Refer to chart on toxicology
Orthene	0.5 pound	76-100%	Good	\$7.00	Simple	Yes	Yes	Refer to chart on toxicology
Dimilin	.03 to .05 pound	76-100%	Good	\$5.00 to \$7.00	Simple	Yes	Yes	Only on forested areas

* 25.0 to 125 million potency units/A

forces, these forces are perpetuated, allowing them to kill more caterpillars. If a gypsy moth dies from disease, it leaves bacteria or virus in the environment to be picked up by other caterpillars who, in turn, pass the disease on to others. Calosoma beetles, birds, or mammals that eat gypsy moths, will continue to prey on them with the next generation in the following year. Therefore, whenever feasible, biological controls are preferable to chemical controls.

Among the methods used for IPM are pheromones, hormones, pathogens, management and release of parasites and predators, sterile male release, silviculture, reliable predictions of outbreaks, accurate cost-benefit assessments for control in vulnerable areas, exploiting the behavioral characteristics of the pest, and public education.

D. Do Nothing

The effects of inaction on tree mortality and stand condition as well as on people are described in Section IV, Impact of Gypsy Moth Outbreaks. The past history of gypsy moth outbreaks in Massachusetts indicated that the outbreaks do not continue unabated for long periods of time. Natural forces suppress the population to endemic numbers. If the nuisance and damage can be tolerated for two to three years, a period of gypsy moth inactivity can be expected to follow.

A P P E N D I X

Determining Financial Losses to the Timber Resource caused by the Gypsy Moth

Formulae I and II were taken from USDA Forest Service Research Paper
NE - 275 and apply to mortality only.

(I.) Immediate Value Loss

(product value) - (conversion cost) / acre = immediate loss

In forest situations product values are obtained by applying tree grades to determine product yields for each particular grade tree and determining what the conversion costs are for each product. Because of the large tracts of land involved sampling is used to gather the data and is expressed on a per acre basis.

(II.) Future Value Loss

Product value at maturity x mortality rate = Expected value loss. To bring this value back to the present apply the following:

$$\text{Expected value loss current dollars} = \frac{\text{expected value loss}}{(1 + i)^n}$$

Where i = interest (growth) rate

Where n = period (no. of years to maturity)

(III.) Value of growth loss

Assumptions can be made concerning financial impacts in relation to reduction in increment (growth).

(Value of annual increment) (% reduction in growth) = annual value loss. This figure could be expressed either annually or periodically. Since the effects of defoliation on increment exceed one year greater accuracy would be obtained by using a periodic (10 yr., 20 yr.) approach.

Toxicological Information

Material	Acute Toxicity			Chronic Toxicity			Fish	Invertebrates	Birds	Mammals	Beneficial Insects	Plants
	Oral	Dermal		Carcino-genecity	Terato-genecity	Muta-genecity						
Carbaryl	0	0		0	?	X	?	X	?	X (deer)	Bees, parasites	Boston ivy
Orthene	0	0		0	0	?	0	*	X	*	X Bees and others	X Apple, elm, maple
Dimilin	0	0		?	0	*	X	X	?	*	*	0
Dylox												

* There is no evidence of mutagenic effects of Dimilin.
 There is some evidence of mutagenic activity of two metabolites.

* Insufficient information available.

Key

X = Probable areas of concern

? = May be an area of concern

0 = Not an area of concern

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